MOBILE COMMUNICATION NETWORK ARCHITECTURE (MCNA) TRANSITION AND INTEROPERABILITY REPORT
(A042)

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1 INTRODUCTION

1.1 BACKGROUND

The Mobile Communication Network Architecture (MCNA) encompasses the aggregate of all voice and data communication capabilities in support of communications, navigation and surveillance (CNS) services for Air Traffic Management (ATM) operations. Like System Wide Information Management (SWIM), MCNA is a key enabling technology for transformation of the National Airspace System (NAS) towards Network Centric Operations (NCO). The MCNA effort represents a System of Systems Engineering (SoSE) based evaluation of the MCNA concept. One focus of this effort is the evaluation of the requirements, architecture and associated transition plan necessary to assure that the air-ground and air-air communications capabilities will support of the needs of SWIM-enabled applications (SEA) to provide NCO. Equally important are the auxiliary efforts of evaluating the certification challenges inherent in MCNA and the determination of the simulation, emulation, and demonstration capabilities necessary to validate the MCNA for use in NEA and SWIM. The goal of this effort is to develop an integrated SoSE approach and technology development roadmap that will provide guidance for ongoing and planned NASA Glenn Research Center (GRC) and FAA research activities including NASA GRC's Advanced CNS Architectures and System Technologies (ACAST) Project and NASA Airspace Systems Program's proposed initiative for the Transformation of the NAS (TNAS).

The MCNA nomenclature was introduced within the SOW of the GCNSS II contract task. As such, it is a common misconception that MCNA refers solely to the "vision" of mobile communications capabilities intended to support the most demanding SWIM-enabled applications including cockpit integration. In fact, all communications to mobile networks in the NAS, such as1090ES, ACARS and FANS are all existing components of the MCNA. In time, these components will likely be augmented by ATN over VDLm2 and VDLm3, UAT and broadband SatCom. Eventually, the NAS will be supported by the suite of enhanced datalink services recommended by the Future Communication System (FCS). The key aspect of MCNA is that it extends voice and data communications to the aircraft during all phases of flight. Figure 1 illustrates how MCNA fits in the Common Data Transport (CDT) portion of the SWIM and thereby a critical infrastructure element for Network Centric Operations (NCO).

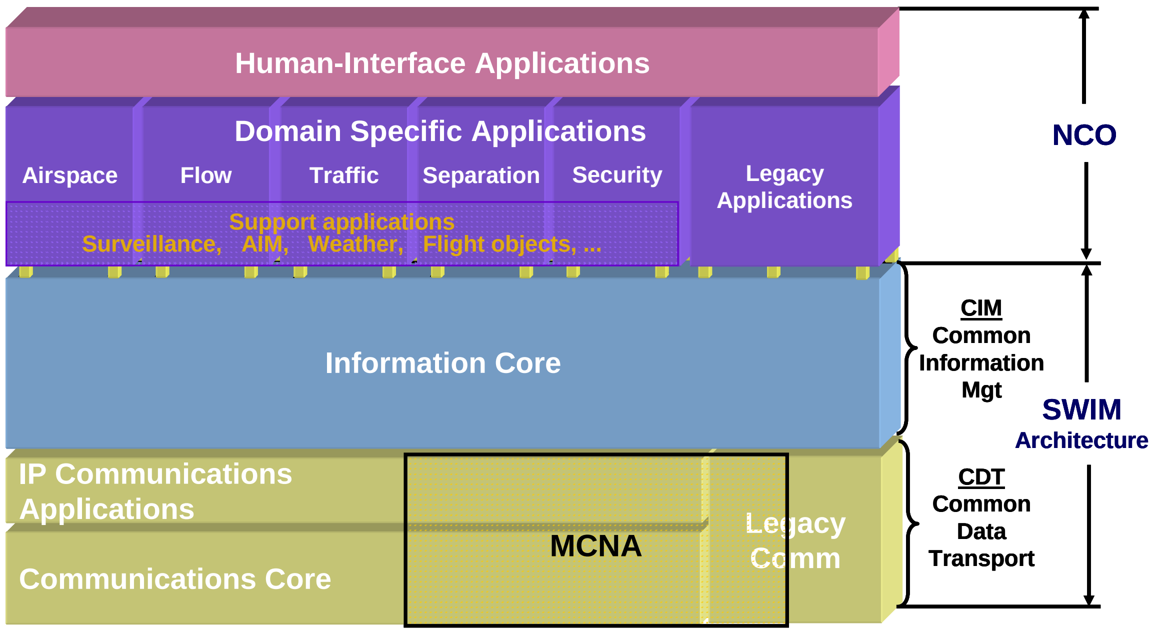

Figure 1: Relationship of MCNA to SWIM and NCO.

While the goal of MCNA is to extend the reach of SWIM information nodes to the aircraft this does not suggest, even in the MCNA vision, that all communications to and from the aircraft will use SWIM as means of information exchange. Basically, SWIM will enable the ubiquitous sharing of information between applications. The sharing of information is a result of integrating applications via common mechanisms. SWIM will support multiple integration frameworks (i.e., .NET, J2EE, CORBA, Web Services) and platforms (i.e., Windows, Linux, etc.) for flexibility and evolutionary reasons. The SWIM environment will enable both anticipated and unanticipated users of information using information discovery mechanisms. The fact that the SWIM environment will support and even promote ubiquitous information sharing doesn't mean that all applications should exchange all information with all other applications. Only authenticated and authorized users of information will be allowed to access it, as determined by the "owner" of the information source.

In early SWIM development and deployment spirals, existing information exchange mechanisms will continue to coexist alongside the new SWIM mechanisms. This will be done for both reliability/availability and backwards compatibility reasons. In some cases, it may make sense to retain information exchange mechanisms outside of SWIM beyond the initial spirals. The desirability of these out-of-band information exchange mechanisms will, in general, be greater for application groups that are tightly coupled, synchronous, unlikely to change and unlikely to be expanded. This will be decided on a case-by-case basis and will require a thorough analysis. In most instances the information exchange mechanisms offered by SWIM will be sufficient.

1.2 PURPOSE AND SCOPE

A sub task in the MCNA effort is the development of concepts and strategies for transitioning from today's disparate communication systems with uneven coverage and insufficient capabilities toward an integrated Mobile Communication Network Architecture that will support System Wide Information Management (SWIM) and Network Centric Operations (NCO). It is this task which is documented in the MCNA Transition and Interoperability (T&I) Report.

The key outputs of the MCNA Transition and Interoperability task is a macro MCNA transition plan and the identification of the major interoperability issues. The starting point is the current MCNA capabilities provided in FAA controlled airspace. The vision of MCNA functionality and capabilities comes from the MCNA architecture task documented in the MCNA Architecture Report, [2]. The transition plans describe potential methodologies on how this functionality and capabilities could be rolled out over time using current and planned communication link technologies.

Note: The detailed aspects of the avionics transition are addressed in the MCNA Architecture Report.

1.3 DOCUMENT ORGANIZATION

Section 1 provides the background and purpose of the MCNA Transition and Interoperability task in relation to the other MCNA tasks and the GCNSS II program overall.

Section 2 describes the approach used in generating the transition plan and determining the interoperability issues.

Section 3 introduces the concepts of the total communication performance levels and describes the allocation of the communication services and MCNA functionality to these timeframes.

Section 4 documents the detailed macro transition plans and highlights the technology gaps that they spotlight.

Section 5 summarizes the MCNA interoperability issues.

Section 6 documents the conclusions of the report and recommendations for further research and analysis in the transition and interoperability area of MCNA.

Appendices provide references and the definition of relevant acronyms.

2 DEFINITIONS AND APPROACH

The main goal of the MCNA Transition subtask is to develop strategies for rolling out MCNA functionality and architecture capabilities over time and to identify resultant technology gaps and interoperability issues. The starting point for this task is the set of detailed tables developed in the Requirements Report [1], and the MCNA Architecture Report, [2]. These tables contain a wealth of quantitative and qualitative data on the MCNA scenarios, MCNA voice and data services, and the MCNA candidate communication links. This data was gathered from industry documents and compiled using the expertise of the MCNA team. The full tables are available in the documents referenced above but abridged versions are reproduced later in this section. Given this wealth of data, the challenge of the MCNA transition subtask was to determine a method of linking the data between these tables and extracting useful information on how MCNA functionality and capabilities could evolve over time. Early in the GCNSS II contract, Microsoft Access database software was selected as the tool for organizing and processing this data and generating the desired information. Section 8 describes the design of the Microsoft database that was generated for use in the transition analysis.

It should be noted, the MCNA transition task considers the deployment of the MCNA infrastructure from a macro level. The results give an indication of technology gaps in the system from a high level. For example, there can be high ranking scenarios that lend themselves to early deployment but the transition plans indicate gaps in communication link technologies for providing the needed communication services in specific airspace domains or to specific aircraft classes. This would suggest a recommendation of expanding the capabilities of the link candidates to provide these services in needed domains or specific aircraft classes. This aspect of the overall MCNA task is addressed in detail in the Technology Gaps and Roadmap task, [3].

The MCNA transition analysis in the GCNSS II contract is the first step in an evolutionary process of MCNA transition work. Resource and schedule constraints limited the amount of peer review of the quantitative and qualitative parameters that define the operational scenarios, candidate links, and communications service/levels. In addition, there are independencies on external factors such as certification process, political and business considerations of aircraft equipage, and communication service requirements development efforts that will need to be fully taken into consideration.

The main tool used in the transition task was a Microsoft Access Database. It was used to capture all the information on the communication services, candidate links, and operational scenarios that is described in the sections that followed. Simple joins, sorting, and filtering were used to organize the information in ways to produce the results of transition task. The design of this Microsoft database is described in section 8 of this Report.

2.1 COMMUNICATION SERVICE CLASSES AND LEVELS

One of the key aspects of the System of Systems Engineering (SoSE) approach, used in the MCNA tasks, is the uncoupling of the voice and data communication performance requirements of applications from the physical architecture. This was achieved by defining a set of communication service classes, each with a common use and attributes. Within each of these classes, different levels of performance requirements were specified. This allows the tailoring of the capabilities of the communication systems to the requirements of the applications and the operations that they in turn support. This reduces the cost of providing communication services by preventing the most stringent performance requirements from driving the design of the entire communication infrastructure.

Table 1 and Table 2 list the voice and data communication classes and service levels respectively. The last column provides an example of the voice and data link operational applications that could be expected to require the communication service. The MCNA Requirements Report, [1], contains a detailed description of the service classes and levels and their corresponding performance requirements. The basis for these service classes and their performance were previous industry efforts on Air/Ground Communication such as MACONDO and PARC Comm. Working Group, [5][6][7][8].

Table 1: Voice Communication Services.

Service Class	Service Level	Designator	Description
Party Line Voice	1	RCP-PLV1	Emergency Party Line Service
	2	RCP-PLV2	Terminal area and surface party line voice
	3	RCP-PLV3	En-route Party line voice
	4	RCP-PLV4	Oceanic, Remote or AOC Party line voice
Selective Addressed Voice	1	RCP-VSA1	En-route and Terminal ATS telephony
	2	RCP-VSA2	Oceanic, Remote, AOC or DHS telephony
	3	RCP-VSA3	Passenger telephony
Broadcast Voice	1	RCP-VB1	Emergency voice broadcast
	2	RCP-VB2	Info broadcast via voice (e.g. ATIS)

Table 2: Data Communication Services.

Service Class	Service Level	Designator	Description
Data Messaging	1	RCP-DM1	Tactical CPDLC: D-ALERT, URCO, ACL, D-TAXI
	2	RCP-DM2	Strategic CPDLC: DLL, ACM, FLUP, D-RVR, PPD, ACL, DCL, D-TAXI, AMC, AUTO-CPDLC
	3	RCP-DM3	Routine CDPLC: DLL, ACM, D-ATIS, D-SIGMET, D-ORIS, DSC
	4	RCP-DM4	AOC "ACARS": OOOI, NOTAM, METAR, TAF, weather request, position report, flight status, fuel status, flight plan request, load sheet request
Trajectory Exchange	1	RCP-TE1	Tactical Trajectory Update: COTRAC, FLIPSY, FLIPINT
	2	RCP-TE2	Strategic Trajectory Update: FLIPINT, ARMAND, GRECO, DYNAV, ACL, DCL, D-TAXI
Broadcast to Aircraft	1	RCP-BTA1	TIS-B for self separation
	2	RCP-BTA2	TIS-B for situational awareness
	3	RCP-BTA3	FIS-B
Broadcast from Aircraft	1	RCP-BFA1	ADS-B for self separation (terminal & surface)
	2	RCP-BFA2	ADS-B for self separation (en-route)
	3	RCP-BFA3	ADS-B for situational awareness
Ground to Air Data	1	RCP-FU1	Tactical SWIM services
	2	RCP-FU2	Strategic SWIM services
	3	RCP-FU3	Informational SWIM services
Air to Ground Data	1	RCP-FD1	Tactical SWIM services
	2	RCP-FD2	Strategic SWIM services
	3	RCP-FD3	Informational SWIM services
Air to Air Data	1	RCP-AAD1	Collision avoidance resolution
	2	RCP-AAD2	Free flight conflict resolution
	3	RCP-AAD3	Self-separation resolution
Video Exchange	1	RCP-V1	ROA aircraft view downlink
	2	RCP-V2	DHS situation downlink
Command & Control	1	RCP-CC1	ROA CC Level 1 - Commercial airspace (maybe) and over populated areas
	2	RCP-CC2	ROA CC Level 2 - SUA over populated areas
	3	RCP-CC3	ROA CC Level 3 - Operation in SUA over unpopulated areas

2.2 AIRSPACE DOMAINS AND AIRCRAFT CLASSES

An important issue for attention in the transition analysis is the differing needs of MCNA functionality for different airspace domains. Table 3 lists the names and definitions of the airspace domains used in the MCNA transition analysis.

Table 3: MCNA Airspace Domains.

Airspace Domain	Definition
Gate	Aircraft at the gate
Surface	Surface and airspace controlled by Tower.
Terminal	Airspace controlled by TRACON
En Route	Airspace controlled by ARTCC
Remote	Airspace in the NAS that due to either terrain blocking of direct line of site communications or the high cost of deployment of communication infrastructure in low aircraft density regions.
Oceanic	Airspace over the ocean where aircraft cannot communicate directly with line of sight (LOS) terrestrial (land) based base stations.
Polar	Airspace surrounding the north and south poles, above 75 degrees north or below 75 degree south, where communication with GEO satellites is not possible

The transition analysis considers categories that distinguish among the unique needs of classes of aircraft traversing the NAS. Table 4 below describes the six aircraft classes that are used in the transition plan analysis. Several of the aircraft classes discussed at the beginning of the contract were combined together when it became difficult to determine unique needs given the moderate level of fidelity of the MCNA effort. Where this combination occurs it is called out in the definition of the MCNA aircraft class.

Table 4: MCNA Aircraft Classes.

Aircraft Class	Definition
Transport	Commercial passenger transport aircraft
Cargo	Commercial cargo aircraft
Business Jet	Small jets. For the purposes of this study, Air Taxis have been combined with this aircraft class. At the fidelity of this contract, differences in the needs and capabilities were not significant. Where issues do arise between the differences in Business Jets and Air Taxis, this will be called out and addressed.
General Aviation (Personal Aircraft)	Small personal aircraft that currently fly in unmanaged airspace. For the purposes of this study, Rotorcraft have been combined with this aircraft class. At the fidelity of this contract, differences in the needs and capabilities were not significant. Where issues do arise between the differences in GA and Rotorcraft, this will be called out and addressed.

Military Aircraft	US military aircraft
UAV	Unmanned Aerial Vehicles. For the purposes of this study, Remotely Operated Aircraft have been combined with this aircraft class. At the fidelity of this contract, differences in the needs and capabilities were not significant. Where issues do arise between the differences in UAV and ROA, this will be called out and addressed.

Another class of aircraft initially under consideration was aerospace vehicles. The mission needs for MCNA, as defined through scenarios analysis, determined that this type of vehicles is out of scope of MCNA in the timeframes under study. It is assumed that these vehicles will use separate communication architecture that will coordinate with the ATM system using special use airspace (SUA) much like the military does today. Some recent developments, such as the success of space ship one, would suggest that this needs to be reconsidered. Including Aerospace vehicles in the transition analysis should be considered for future MCNA analysis.

2.3 MCNA SCENARIOS

The MCNA scenario activity began with a broad survey of potential ATM scenarios that would be enhanced or enabled through MCNA. These scenarios, initially numbering over 70, were taken from many different industry sources. A quick pass through enabled the removal from considerations of many of these as being redundant, non-scenarios and scenarios that did not directly address any MCNA requirements. The resulting 35 scenarios were further reduced to 8 though benefit/risk analysis that is described in detail in the MCNA Requirements Report, [1]. Table 5 below lists these eight scenarios and describes their voice and data communication requirements and coverage of different airspace domains and aircraft classes.

Table 5: Selected MCNA Scenarios.

Scenario Number	Scenario	Description	Communication Services												Airspace Domain							Aircraft Class						Information Classes			
			Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trjaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control	Gate	Surface	Terminal	En-route	Remote	Oceanic	Polar	Transport	Cargo	Military	UAV/ROA	GA - Business	GA - Personal	Surveillance	Weather	AIM	Flight Objects
1	Deploy FIS-B Nationally	Free access nationwide for basic weather and NAS status information to equipped aircraft						3							Y	Y	Y	Y	N	N	N	Y	Y	Y	N	Y	Y	N	Y	Y	N
5	Autonomous Hazard Weather Alert Notification	Enhanced situations awareness via immediate simultaneous dissemination of hazardous weather to service providers, aircraft and airlines. **These products shall include microburst, turbulence and windshear warning in terminal airspace and shall be provided both automatically or upon pilot request.**			2	2		2		2					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N
10	Datalink to reduce routine workload	Expanded use of datalink for routine service provide activities to reduce workload.	2			2									Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	N	Y
15	Enhanced Emergency Alerting	Using GPS position and aircraft ID, locate distressed or downed aircraft through ADS-B							1						N	N	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N
20	Optimize Runway Assignments	Improve sequencing and spacing of arriving aircraft with tools for better management of runway assignment. Tool provide and deliver pilot instructions and wake vortex warnings. Also provides hooks for a path from runway to en-route to improve flow.					2		1	2					N	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N	N	N	Y	Y
25	Controller awareness of ACAS resolutions	The system shall support the delivery and display to controllers of any resolution advisories generated by aircraft ACAS systems.				1									N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N
29	Aircraft push of security video and aircraft performance during emergency	For the purposes of security, it may be valuable to have mechanisms to trigger the downlink of streaming video and audio of the cockpit and cabin environments and send down critical aircraft performance data.							2		2		2		Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	N	N	N
32	Push of Security advisories to aircraft	When an airspace emergency occurs, it would be desirable to quickly distribute notification to affected aircraft, AOC/FOC, ARTCC and other government agencies				2									Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N

2.4 CANDIDATE LINK SYSTEMS

Table 6 below shows the candidate link systems considered in the transition task. Detailed descriptions of each candidate link are available in the MCNA Architecture Report, [2]. The table includes a combination of existing and planned systems as well as technologies that could be used to defined future systems.

Table 6: Candidate Link Systems.

							Communication Services												Airspace Domain							Aircraft Class					
Candidate Link Type	Link ID Number	Associated Networking Protocols	Spectrum	Total Cost	SWIM Support (3 is highest)	Availability (date)	Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trjaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control	Gate	Surface	Terminal	En-route	Remote	Oceanic	Polar	Transport	Cargo	Military	UAV/ROA	GA - Business	GA - Personal
Air-Ground Communications																															
VHF Analog Voice	1	NA	VHF	3	0	2005	1		1										Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y
HF Analog Voice	2	NA	HF	3	0	2005		3											N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N
Plain old ACARS (POA)	3	ACARS	VHF	2	1	2005				3									Y	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N
VDLm2	4	ACARS	VHF	2	1	2005				3				3	3				Y	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N
	5	CLNP	VHF	3	2	2010			2	2	2			3	3				Y	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N
	6	IP	VHF	6	2	2010			2	3		3	3	3	3				Y	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N
	7	NA (VDL-B)	VHF	2	2	2005						2							Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y
VDLm3	8	CLNP	VHF, DME	6	2	2020				1	1							2	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	Y	N
	9	Voice			1	2015	1		1										Y	Y	Y	Y	N	N	N	Y	Y	N	Y	Y	N
HFDL	10	ACARS	HF	3	1	2005				3									N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N
	11	CLNP		4		2010																									
3G	12	IP	DME	7	3	2020	3	2	1	1	1	1	1	1	1		2	2	Y	Y	Y	Y	N	N	N	Y	Y	N	N	Y	Y
Satellite Communications																															
Aero-H	13	ACARS (data-2)	AMSRS	6	1	2005		2		2	2								Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N
	14	CLNP (data-3)		7		2010																									
	15	IP (data-3)		8		2010																									
Swift-64	16	IP	AMSRS	7	1	2005		3	1	3		3	3	3	3			3	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N
Swift-Broadband	17	IP	AMSRS	5	3	2010	3	2	1	1	1	2	3	1	1		2	2	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
SDARS	18	IP	S-Band	5	2	2015			1			2							Y	Y	Y	Y	Y	N	N	Y	Y	N	N	Y	Y
SDLS	19	NA	AMSRS	8	2	2015	3	1	1	1	1	2	3	1	1				Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Iridium	20	Layer-2	L-Band	5	1	2005		3		3		3							Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Connexion by Boeing	21	IP	FSS	8	3	2005	4	3	2	3		3	3	3	3		2	3	N	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N
Air-Air Communications																															
1090-ES	22	CLNP	DME	1	1	2010				2	2					1			N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N
	23	Layer-2	DME		1	2005						1	1						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
UAT	24	Layer-2	DME	5	2	2010						1	1						N	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y
VDLm4	25	CLNP	VHF	3	1	2010							1			1			N	N	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y
B-VHF	26	CLNP	VHF, DME	9	3	2025	1	1	1	1	1			1	1	1		2	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	Y	N
	27	IP					1	1	1	1	1	1		1	1	1		2													
P-25	28	IP	DME	8	1	2020	1	1	1	3									Y	Y	Y	N	N	N	N	Y	Y	Y	N	Y	Y
P-34	29	IP	DME, MLS	10	3	2025	2	2	1	1	1	1	1	1	1	2	2	2	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	Y	N
Airport Communications																															
Aiport Data Link (ADL)	30	NA	MLS	7	3	2025	2	1	1	1	1	1	3	1	1		1	1	Y	Y	N	N	N	N	N	Y	Y	N	N	Y	Y
IEEE 802.11	31	IP	ISM	4	3	2010			2	3		3		3	3				Y	N	N	N	N	N	N	Y	Y	N	N	Y	Y
	32	CLNP				2015			2	3				3	3																
IEEE 802.16	33	IP	ISM, MLS	6	3	2020	2	1	1	1	1	1	1	1	1	1	1	1	Y	Y	N	N	N	N	N	Y	Y	N	N	Y	Y
	34	CLNP					2	1	1	1	1			1	1	1	1	1													
IEEE 802.20	35	IP	ISM, DME	6	3	2025	2	2	1	1	1	2	2	1	1		2	2	Y	Y	N	N	N	N	N	Y	Y	N	N	Y	Y
	36	CLNP					2	1	1	1	1		2	1	1		2	2													
TETRA I/II	37	IP	DME	6	2	2025	1	1	1	1	1	1	1					1	Y	Y	N	N	N	N	N	Y	Y	N	N	Y	Y

Each of these candidate links had originally associated with it four risk metrics (Technology Readiness Level (TRL), Standardization, Certifiability, Political) and four cost metrics (System, Maintenance, Service, Avionics). The values of these individual risks and detailed descriptions of the Candidate Links are found in the MCNA Architecture Report. The values for the individual metrics were based on a relative comparison of the links based on engineering knowledge of the MCNA team and input from a small team of operational experts. For both risk and cost low numbers are good while higher numbers are bad. These were aggregated to come up with a single metric for comparison between candidate communication links called Total Cost, column 5 in Table 6.

Two methods were used to combine the risk and cost. Initially, each risk metric of a candidate link was linearly summed together and then normalized by the maximum sum for all the candidate links. This was also done for the cost metrics for the candidate links. These were summed together and then normalized to set the maximum value to ten and rounded to the nearest integer. For example in VHF voice the for risk metrics (TRL, Standardization, Certifiability, and Political) are (1,1,1,1) and the cost metrics (System, Maintenance, Service and Avionics) are (0,4,0,0). The calculation for Total cost is then,

$$round\left(10\times\left(\frac{(1+1+1+1)}{12}+\frac{(0+4+0+0)}{12}\right)\Big/0.9167\right)=4,$$

where the two number 12’s in the denominator normalize the individual summation of the risk and cost and the denominator containing 0.9167 normalizes the combination of the two. The same calculation for SwiftBroadband is,

$$round\left(10\times\left(\frac{(2+2+2+2)}{12}+\frac{(0+0+2+4)}{12}\right)\Big/0.9167\right)=6.$$

The second method was identical except that each metric was expressed as an exponent to the number two before summing them together. The same calculations for VHF voice and SwiftBroadband that were shown for the linear summation are shown for this second method below. The numbers in the denominators change as the maximums across all candidate links change with the different calculations in the summations. First for VHF Voice,

$$round\left(10\times\left(\frac{(2^1+2^1+2^1+2^1)}{36}+\frac{(2^0+2^4+2^0+2^0)}{50}\right)\Big/0.8611\right)=3,$$

and next for SwiftBroadband,

$$round\left(10\times\left(\frac{(2^2+2^2+2^2+2^2)}{36}+\frac{(2^0+2^0+2^2+2^4)}{50}\right)\Big/0.8611\right)=5.$$

Figure 2 below shows the results of the two methods (log and linear). The log method was chosen as it provided better distinction among the 37 candidate link systems. This total cost metric is used later for differentiation between sets of candidate links that meet the service class and service level requirements of operational scenarios.

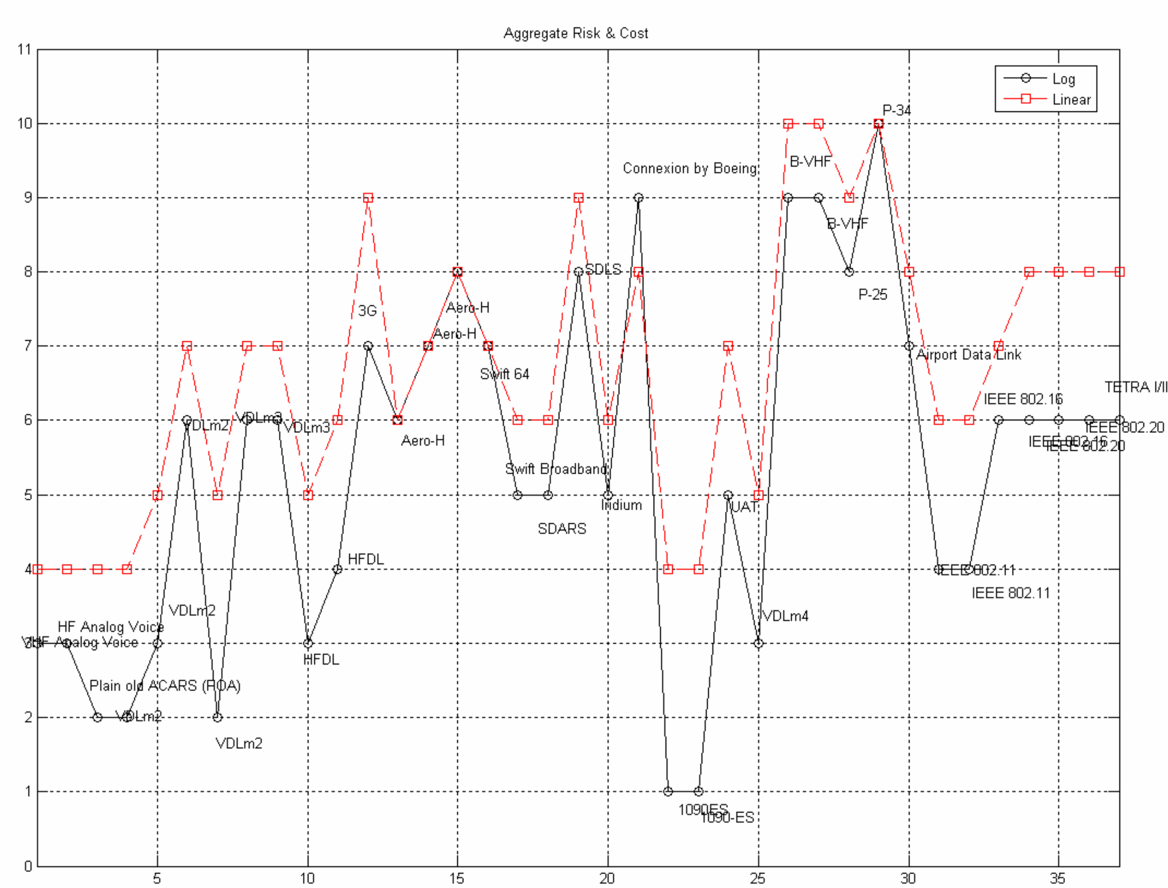

Figure 2: Candidate Links Total Cost (Cost & Risk).

3 TOTAL COMMUNICATION SYSTEM PERFORMANCE LEVELS

In this section, the total communication system performance (TCSP) levels for each timeframe are defined. These TCSP levels spans the currently available MCNA capabilities to the vision of the MCNA in the 2030 timeframe. The TCSP levels were determined by allocating the communication services and service levels to four different deployment spirals/time frames. The purpose of this activity is to provide a high level view of the deployment of communication services over time leading to the extension of SWIM to the aircraft and the and NCO. The availability of a communication service in a particular timeframe was determined though examination of the communication links available in that time period. Basing the possibility of service class and level exclusively on the availability of communication links that can provide a service class and level produced overly optimistic predictions of TCSP levels. The engineering judgment of a subset of the MCNA team was used to adjust the service classes and levels in each TCSP. In later TCSP levels where predictions become more difficult the possible service class and level in a specific airspace domain and aircraft class can be bounded by some simple operational assumptions. For example, ADS broadcast does not make much sense while an aircraft is at the gate. Thus even in the vision time frame the broadcast from aircraft data communication service will not need to be provided in the gate airspace domain.

The TCSP are defined by the service classes/service levels available in that timeframe. This is illustrated in tables where for each service class the highest service level possible are indicated with service level as defined earlier in Table 1 and Table 2. The tables contained in the following section are color coded to reflect the confidence of the MCNA team of the coverage of the communication service in the specific airspace domain or aircraft class. Green represents the most confidence, yellow indicates less confidence, and red represents the least confidence.

3.1 CURRENT (2005)

This section outlines the current MCNA capabilities in the NAS. These capabilities provide the baseline from which MCNA will evolve. The current use of MCNA capabilities for ATC purposes is primarily voice based with limited use of datalink. Currently the data services in FAA controlled airspace consists of such services as FIS in the En Route domain, oceanic clearances, and some basic weather reporting (MDCRS).

Table 7 below describes the MCNA services currently available in different airspace domains to equipped aircraft from the various aircraft classes. The numbers indicate the highest service level of that class possible for that column, airspace domain or aircraft class. Lower numbers represent higher service performance levels; see Table 1 and Table 2. An entry of “NA” indicates that the service class is not yet available or intended for that airspace domain or aircraft class. The fact that a service class is achievable in an airspace domain and to an aircraft class does not imply ubiquitous coverage. Communication service availability will be limited to chosen geographic regions where operational improvements are warranted and only to those aircraft that choose to properly equip. The degree of confidence that the communication service class and level will be available by the relevant timeframe is indicated by the color coding described earlier. A detailed discussion of methods and strategies to incentivize aircraft operators to equip is beyond the scope of this study.

As seen in Table 7, voice services are currently the most pervasive with data services limited to properly equipped Transport and Cargo aircraft in select airspace domains. The limited voice services available in the Remote domain reflect its definition as geographic regions with currently limited communication coverage. It will be demonstrated that as MCNA services roll out, the Remote airspace domain will begin to migrate toward the current definition of the En Route airspace domain.

Table 7: Current MCNA Total Communication System Performance.

	Airspace Domains							Aircraft Classes					
Communication Service Class	Gate	Surface	Terminal	En Route	Remote	Oceanic	Polar	Transport	Cargo	Business Jet	GA	Military	UAV/ROA
VOICE													
Party Line Voice	1	1	1	1	NA	NA	NA	1	1	1	1	1	NA
Selective Addressed Voice	NA	NA	NA	2	2	2	NA	2	2	2	3	2	NA
Broadcast Voice	1	1	1	1	NA	NA	NA	1	1	1	1	1	NA
DATA													
Data Messaging	3	3	3	3	2	2	3	2	2	NA	NA	NA	NA
Trajectory Exchange	NA	NA`	NA	NA	2	2	NA	2	2	NA	NA	NA	NA
Broadcast to Aircraft	NA	3	3	3	NA	NA	NA	3	3	3	3	NA	NA
Broadcast from Aircraft	NA	NA	NA	NA	NA	3	NA	3	3	NA	NA	NA	NA
Ground to Air Data	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Air to Ground Data	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Air to Air Data	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Video Exchange	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Command and Control	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Currently SWIM services do not exist. Thus Air to Ground Data and Ground to Air Data service classes are not currently available. These communication services were defined to support general tactical, strategic, and informational SWIM services, see Table 2.

3.2 NEAR-TERM (2005-2010)

The focus in the near term is to expand the coverage of data communication services to additional airspace domains and aircraft classes. Table 8 lists the service classes and levels possible in different airspace domains and to different aircraft classes. The deployment of data services has expanded to include some lower level services to business jets. General aviation remains mostly limited to voice services. In addition, Video Exchange data services become available on Transport and Cargo aircraft for security applications.

Datalink equipage rates for Transport, Cargo, and Business Jets should have increased significantly. This will be encouraged by allowing properly equipped aircraft access to more airspace and more efficient ATC operational procedures. The equipage of General Aviation and Military are limited to those that wish to operate in designated airspace.

Even through the UAV/ROA category of aircraft classes includes remotely controlled aircraft (ROA), whose operators are on the ground, in the early stages it will still require voice communications to the aircraft. Much of the research in this area, [10], assumes that to minimize impact on the NAS, ROA will appear no different than other aircraft. They will be on the same party line voice radio channels as piloted aircraft with the ROA relaying this information to its ground based operators via other communication links. Requirements for ADS in some regions will also necessitate that the NAS support Broadcast to Aircraft service to UAV.

Table 8: Near-Term MCNA Total Communication System Performance.

	Airspace Domains							Aircraft Classes					
Communication Service Class	Gate	Surface	Terminal	En Route	Remote	Oceanic	Polar	Transport	Cargo	Business Jet	GA	Military	UAV/ROA
VOICE													
Party Line Voice	1	1	1	1	4	4	NA	1	1	1	1	1	3
Selective Addressed Voice	2	2	2	2	2	2	3	2	2	2	NA	2	NA
Broadcast Voice	1	1	1	1	1	1	NA	1	1	1	1	1	1
DATA													
Data Messaging	2	2	2	1	1	1	3	1	1	1	NA	NA	NA
Trajectory Exchange	2	2	2	1	1	1	NA	1	1	1	NA	NA	NA
Broadcast to Aircraft	3	2	2	2	2	2	NA	2	2	2	3	NA	NA
Broadcast from Aircraft	NA	3	3	3	3	3	3	3	3	3	NA	NA	3
Ground to Air Data	3	3	3	3	3	3	NA	3	3	NA	NA	NA	NA
Air to Ground Data	3	3	3	3	3	3	NA	3	3	NA	NA	NA	NA
Air to Air Data	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Video Exchange	2	2	2	2	2	2	NA	2	2	NA	NA	NA	NA
Command and Control	NA	NA	NA	NA	3	NA	NA	NA	NA	NA	NA	NA	3

MCNA support of SWIM in the near term will be limited. The deployment of SWIM in this time frame is focused on transforming the information exchange on terrestrial networks. This early SWIM deployment focus is named Information Migrations in the GCNSS II documentation. Figure 3 provides some context to the relationship between MCNA, SWIM, and applications in this timeframe. MCNA only provides direct support to a thin slice of SWIM enabled applications. The prime candidates for deploying SWIM to aircraft in this timeframe are non safety of life services. This is reflected in Table 8 by the arrival of Air to Ground Level-3 and Ground to Air Service Level-3 (Informational SWIM services) for Transport and Cargo Aircraft. The other communications services will only indirectly support SWIM by allowing SWIM aggregated information to be sent over data links to applications on aircraft. This would most likely be in the form of the Broadcast to Aircraft service class. Note that levels 2 and 3 correspond to TIS-B for situational awareness and FIS-B respectively.

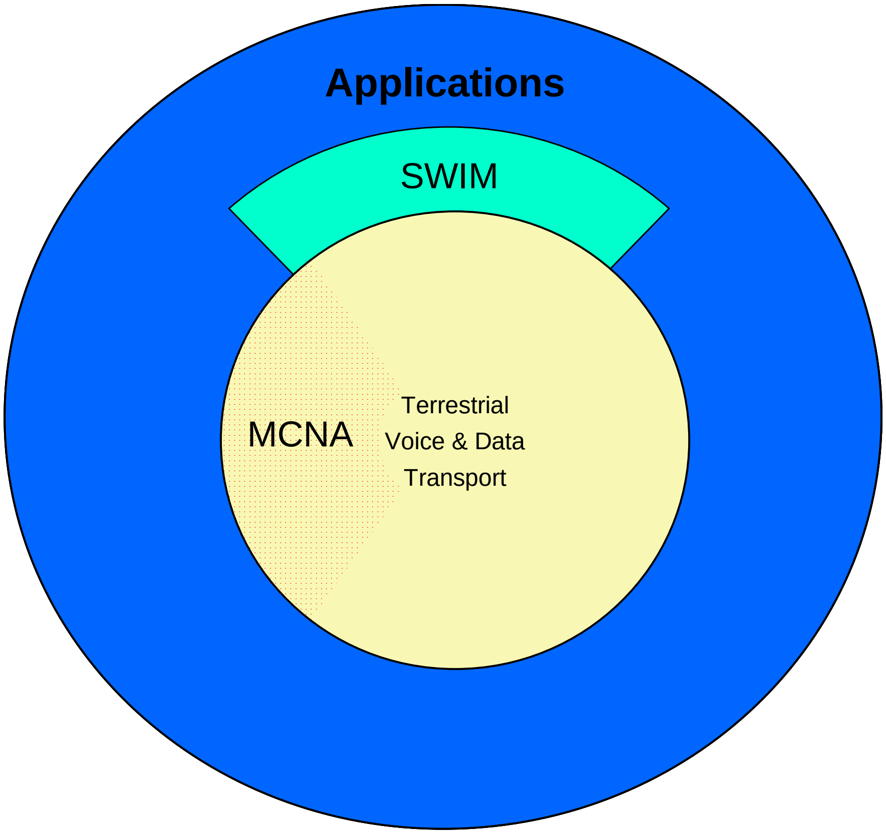

Figure 3: MCNA, SWIM, Application Relationship Diagram (Near-Term).

3.3 MID-TERM (2010-2020)

It is during this timeframe, 2010-2020, that data services will overtake voice as the primary means of ATC communications in the En Route and Oceanic airspace domains. This follows similar assumptions as the latest version of the FCS ICOCR, [5]. Voice communications services will still be available for emergency and back up purposes. Data communication services are available across all airspace domains and all aircraft classes. Equipage rates should be very high for the Transport and Cargo aircraft classes. Inroads into general aviation, business jets, and military aircraft are significant. In fact, it is believed that high end business jets might be the pace setters for deployment of air to ground and ground to air services. As mentioned previously, the FAA will need to develop an effective approach to incentivize equipage of these aircraft classes via some combination of penalties and rewards.

The service levels available for all the service classes are improving. Video exchange for downlink of out the window (OTW) view for ROA becomes available. Also, trajectory exchange shows up for UAV/ROA because it involves uploading information directly to an aircraft's CMU. This service is colored red to indicate that this is still probably a reach for this timeframe.

Table 9: Mid-Term MCNA Total Communication System Performance.

Communication Service Class	Airspace Domains							Aircraft Classes					
	Gate	Surface	Terminal	En Route	Remote	Oceanic	Polar	Transport	Cargo	Business Jet	GA	Military	UAV/ROA
VOICE													
Party Line Voice	1	1	1	1	3	3	NA	1	1	1	1	1	2
Selective Addressed Voice	1	1	1	1	2	2	3	1	1	1	NA	1	NA
Broadcast Voice	1	1	1	1	1	1	NA	1	1	1	1	1	1
DATA													
Data Messaging	1	1	1	1	1	1	3	1	1	1	NA	1	NA
Trajectory Exchange	1	1	1	1	1	1	NA	1	1	1	NA	1	1
Broadcast to Aircraft	3	2	2	2	2	2	NA	2	2	2	3	NA	NA
Broadcast from Aircraft	NA	1	1	2	2	2	2	1	1	1	3	NA	2
Ground to Air Data	2	2	2	2	2	2	NA	2	2	2	NA	NA	NA
Air to Ground Data	2	2	2	2	2	2	NA	2	2	2	NA	NA	NA
Air to Air Data	NA	NA	2	2	3	3	3	2	2	2	NA	NA	NA
Video Exchange	2	2	2	1	1	1	NA	2	2	NA	NA	NA	1
Command and Control	NA	NA	NA	2	3	3	NA	NA	NA	NA	NA	NA	2

Figure 4 below shows the relationship between MCNA and SWIM during the Mid-Term TCSP period. SWIM has migrated from application running on the ground to application running on hosts on the aircraft. The Ground to Air and Air to Ground communication services now support strategic SWIM services (Level 2).

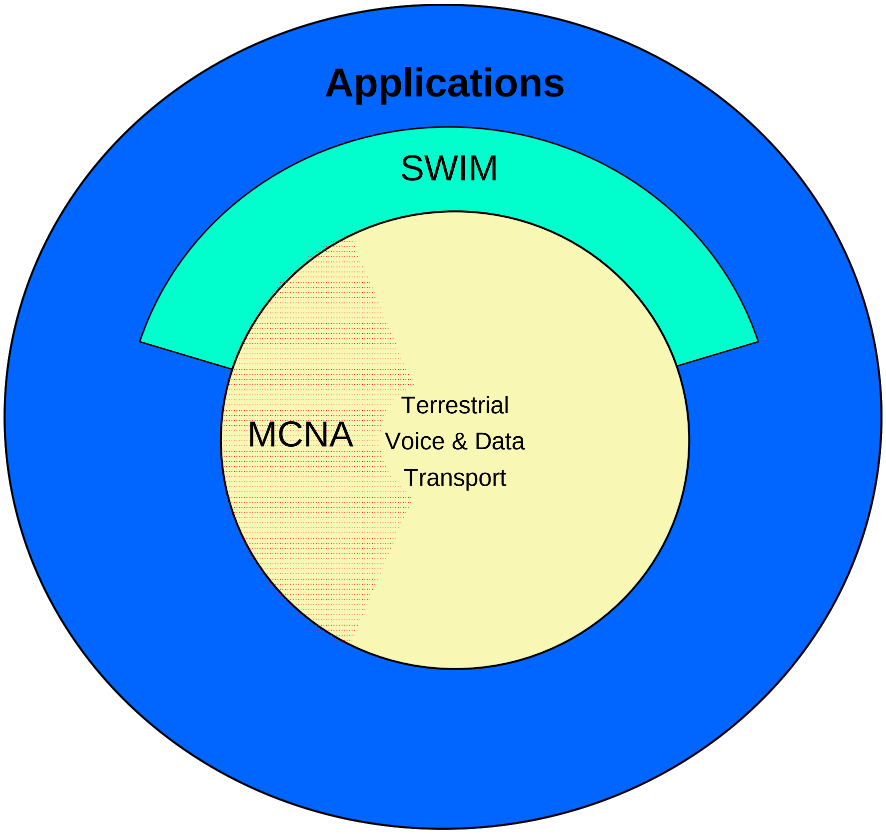

Figure 4: MCNA, SWIM, Application Relationship Diagram (Mid-Term)

3.4 VISION (2020 – 2030)

The 2020-2030 timeframe sees the fruition of the MCNA vision. Table 10 shows the deployment of communication service classes and levels possible in each airspace domain and to each aircraft class for the Vision TCSP. Equipage rate are high for most classes of aircraft. Each airspace domain can provide the highest communication service level that makes sense for its operational needs. For example, the Gate has relatively low levels of data communication services because that is all that is required in this domain. In the same airspace domain, broadcast from aircraft is still not provided since ADS broadcast still does not make sense when the aircraft is sitting at the Gate.

Table 10: Vision Total Communication System Performance.

Communication Service Class	Airspace Domains							Aircraft Classes					
	Gate	Surface	Terminal	En Route	Remote	Oceanic	Polar	Transport	Cargo	Business Jet	GA	Military	UAV/ROA
VOICE													
Party Line Voice	1	1	1	1	1	1	NA	1	1	1	1	1	1
Selective Addressed Voice	1	1	1	1	2	2	2	1	1	1	1	1	NA
Broadcast Voice	1	1	1	1	1	1	NA	1	1	1	1	1	1
DATA													
Data Messaging	1	1	1	1	1	1	2	1	1	1	1	1	NA
Trajectory Exchange	2	2	1	1	1	1	2	1	1	1	1	1	1
Broadcast to Aircraft	3	1	1	1	1	1	3	1	1	1	1	1	NA
Broadcast from Aircraft	NA	1	1	2	2	2	2	1	1	1	1	1	1
Ground to Air Data	2	1	1	1	1	1	NA	1	1	1	1	1	NA
Air to Ground Data	2	1	1	1	1	1	NA	1	1	1	1	1	NA
Air to Air Data	NA	NA	1	1	1	1	1	1	1	1	1	1	NA
Video Exchange	2	1	1	1	1	1	NA	2	2	NA	NA	NA	1
Command and Control	NA	1	1	1	3	3	3	NA	NA	NA	NA	NA	1

In the vision state, many of the applications running on hosts on the aircraft will use SWIM to exchange information with applications running on hosts on the ground or on other aircraft. From the SWIM perspective, these applications will appear no different than those that reside on hosts on the ground.

Figure 5 illustrates the relationship between SWIM, MCNA, Applications, and Terrestrial Voice and & Data Transport. Note, that SWIM does not completely envelop the MCNA and terrestrial voice & data transport. This is because there will always be some sharing of information between applications where either the SWIM does not add value or whose performance requirements cannot be met by SWIM in a cost effective way. For example, voice communication applications would probably not use SWIM as the means for exchanging digital voice data. However SWIM could be useful for auxiliary data exchanges that would be part of a voice communication application such as directory look up. Another example would be Command and Control of ROA. The strict availability and latency requirements of this communication services may not be well suited for SWIM.

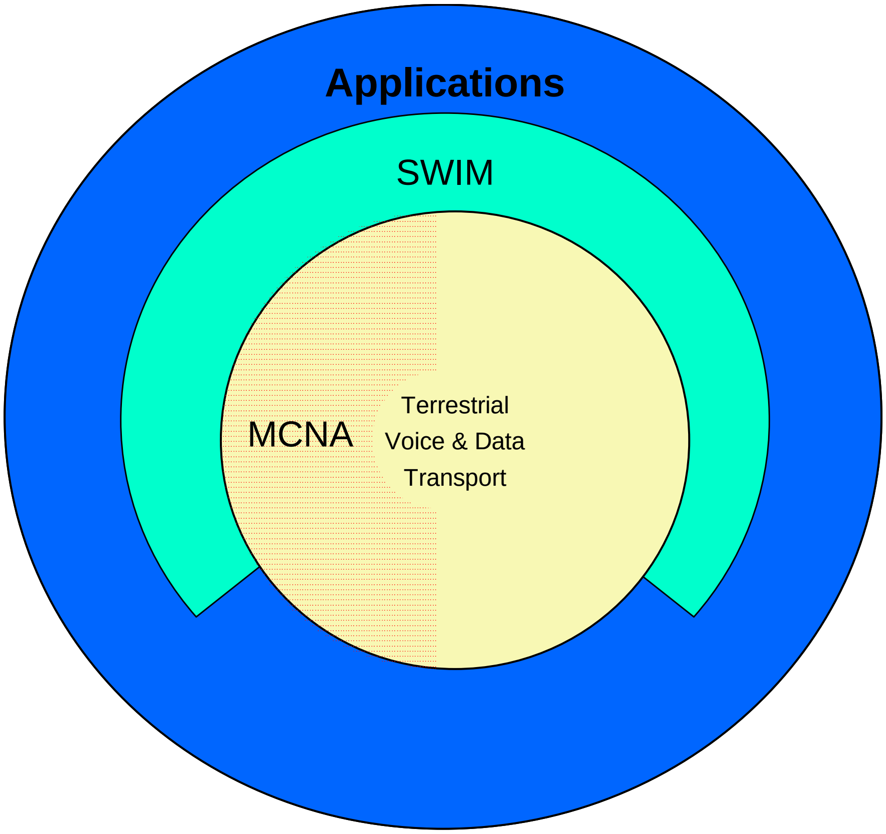

Figure 5: MCNA, SWIM, Application Relationship Diagram (Vision)

4 MCNA TRANSITION STRATEGIES AND ISSUES

Once the information from the requirements and architecture tasks was entered into the Microsoft Access database, the data was then organized to provide insight into potential transition strategies. This section documents the results of the analysis using database queries coupled with some manual data manipulation.

4.1 SCENARIO COVERAGE ANALYSIS

One of the key outputs of the transition tasks is the determination of the potential technology holes and coverage gaps. This section contains information illustrating how well the current set of candidate communication links support the selected MCNA scenarios. Detailed descriptions of these scenarios can be found in the MCNA Requirements Report, [1]. Detailed descriptions of the candidate link systems are found in the MCNA Architecture Report, [2].

4.1.1 Scenario 1: Deploy FIS-B Nationally

Table 11 shows the results of a query for Scenario #1 (Deploy FIS Nationally). The first and second columns indicate the service classes and levels required for this scenario. Columns four through nine provide information on candidate communication links that can meet the service class and corresponding service level. The candidate links are sorted by Total Cost (lowest to highest) as indicated in column 6, Total Cost. The remaining columns indicate for each technology the airspace domain and aircraft classes that have coverage from the candidate communication link.

- A green “X” indicates the scenario requires coverage in a specific domain or aircraft class and the candidate link can meet that requirement.
- A red “O” indicates that the scenario requires coverage and the candidate link cannot meet that requirement.
- A black “NA” indicates that the scenario does not require coverage in that specific airspace domain or aircraft class.

This scenario only requires broadcast to aircraft level 3 (The definition of which is FIS-B) which can easy be met in the near future by 1090ES (layer 2) and VDLm2 (layer 2). Later deployments of technologies will increase flexibility by enabling migration of the service to SWIM and increase the choices of equipage used to access this service.

Table 11: Scenario 1 Data Services Coverage.

Service Class	Level	Comm. ID	Technology	Level	Total Cost	Year	Protocol	SWIM Support	Domain Holes	Gate	Surface	Terminal	Enroute	Remote	Oceanic	Polar	AirClass Holes	Transport	Cargo	Business Jet	GA	Military	UAV
Broadcast to Aircraft	3	23	1090-ES	1	1	2005	Layer-2	1	0	X	X	X	X	NA	NA	NA	1	X	X	X	0	X	NA
Broadcast to Aircraft	3	7	VDLm2	2	2	2005	NA	2	0	X	X	X	X	NA	NA	NA	0	X	X	X	X	X	NA
Broadcast to Aircraft	3	31	IEEE 802.11	3	4	2010	IP	3	3	X	0	0	0	NA	NA	NA	1	X	X	X	X	0	NA
Broadcast to Aircraft	3	24	UAT	1	5	2010	Layer-2	2	1	0	X	X	X	NA	NA	NA	3	0	0	X	X	0	NA
Broadcast to Aircraft	3	18	SDARS	2	5	2015	IP	2	0	X	X	X	X	NA	NA	NA	0	X	X	X	X	X	NA
Broadcast to Aircraft	3	17	Swift Broadband	2	5	2010	IP	3	0	X	X	X	X	NA	NA	NA	0	X	X	X	X	X	NA
Broadcast to Aircraft	3	20	Iridium	3	5	2005	Layer-2	1	0	X	X	X	X	NA	NA	NA	0	X	X	X	X	X	NA
Broadcast to Aircraft	3	33	IEEE 802.16	1	6	2020	IP	3	2	X	X	0	0	NA	NA	NA	1	X	X	X	X	0	NA
Broadcast to Aircraft	3	37	TETRA I/II	1	6	2025	IP	2	2	X	X	0	0	NA	NA	NA	0	X	X	X	X	X	NA
Broadcast to Aircraft	3	35	IEEE 802.20	2	6	2025	IP	3	2	X	X	0	0	NA	NA	NA	1	X	X	X	X	0	NA
Broadcast to Aircraft	3	6	VDLm2	3	6	2010	IP	2	0	X	X	X	X	NA	NA	NA	2	X	X	X	0	0	NA
Broadcast to Aircraft	3	12	3G	1	7	2020	IP	3	0	X	X	X	X	NA	NA	NA	1	X	X	X	X	0	NA
Broadcast to Aircraft	3	30	Airport Data Link	1	7	2025	NA	3	2	X	X	0	0	NA	NA	NA	1	X	X	X	X	0	NA
Broadcast to Aircraft	3	16	Swift 64	3	7	2005	IP	1	0	X	X	X	X	NA	NA	NA	1	X	X	X	0	X	NA
Broadcast to Aircraft	3	19	SDLS	2	8	2015	NA	2	0	X	X	X	X	NA	NA	NA	0	X	X	X	X	X	NA
Broadcast to Aircraft	3	21	Connexion by Boeing	3	9	2005	IP	3	2	0	0	X	X	NA	NA	NA	1	X	X	X	0	X	NA
Broadcast to Aircraft	3	27	B-VHF	1	9	2025	IP	3	0	X	X	X	X	NA	NA	NA	2	X	X	X	0	0	NA
Broadcast to Aircraft	3	29	P-34	1	10	2025	IP	3	0	X	X	X	X	NA	NA	NA	2	X	X	X	0	0	NA

Before moving on to additional scenarios another aspect of the organization and formatting of Table 11 should be mentioned as it applies to the all coverage tables that follow. A candidate link is uniquely defined by Technology and the Protocol, columns four and eight. Further detail on each Candidate link can be found in Table 2 in Section 2.4.

4.1.2 Scenario 5: Autonomous Hazard Weather Alert Notification.

Table 12 and Table 13 summarize the voice services coverage and data service coverage respectively for Scenario #5. An important distinction of this scenario is that any one of the three data and one voice communication services can meet the service requirements of this scenario. Initially, analog voice and VDLm2 (layer 2) data could provide the necessary communication services for this scenario in all airspace classes and for all airspace domains except for Remote, Oceanic, and Polar. Later, satellites services such as Swift Broadband can fill the holes in the Remote and Oceanic regions via several, if not all, of the communication services that could support this scenario.

This still leaves the polar airspace domain uncovered. There are technologies that can support communication in the polar domain (HFDL, Iridium) but they cannot meet the services levels specified for this scenario. The number of flight through polar airspace is quite limited. As such, it is typically difficult to justify the cost of developing a new candidate link to address scenarios within this airspace. This suggests that a special operational scenario be developed for the polar airspace domain that provides aircraft in that region as much of the information as possible within the limitations of the communication services currently available. This would be much cheaper than developing new candidate links to provide these service levels in the polar airspace domain.

Table 12: Scenario 5 Voice Services Coverage.

Service Class	Level	CommSys_ID	Technology	Level	Total Link Cost	Protocol	Year	SwimSupport	Domain Holes	Gate	Surface	Terminal	En Route	Remote	Oceanic	Polar	Airclass Holes	Transport	Cargo	Business Jet	GA	Military	UAV
Broadcast Voice	2	1	VHF Analog Voice	1	3	NA	2005	0	3	X	X	X	X	O	O	O	0	X	X	X	X	X	X
Broadcast Voice	2	5	VDLm2	2	3	CLNP	2010	2	3	X	X	X	X	O	O	O	3	X	X	X	O	O	O
Broadcast Voice	2	32	IEEE 802.11	2	4	CLNP	2015	3	6	X	O	O	O	O	O	O	2	X	X	X	X	O	O
Broadcast Voice	2	31	IEEE 802.11	2	4	IP	2010	3	6	X	O	O	O	O	O	O	2	X	X	X	X	O	O
Broadcast Voice	2	17	Swift Broadband	1	5	IP	2010	3	1	X	X	X	X	X	X	O	0	X	X	X	X	X	X
Broadcast Voice	2	18	SDARS	1	5	IP	2015	2	3	X	X	X	X	X	O	O	0	X	X	X	X	X	X
Broadcast Voice	2	37	TETRA I/II	1	6	IP	2025	2	5	X	X	O	O	O	O	O	1	X	X	X	X	X	O
Broadcast Voice	2	33	IEEE 802.16	1	6	IP	2020	3	5	X	X	O	O	O	O	O	2	X	X	X	X	O	O
Broadcast Voice	2	36	IEEE 802.20	1	6	CLNP	2025	3	5	X	X	O	O	O	O	O	2	X	X	X	X	O	O
Broadcast Voice	2	34	IEEE 802.16	1	6	CNLP	2020	3	5	X	X	O	O	O	O	O	2	X	X	X	X	O	O
Broadcast Voice	2	35	IEEE 802.20	1	6	IP	2025	3	5	X	X	O	O	O	O	O	2	X	X	X	X	O	O
Broadcast Voice	2	6	VDLm2	2	6	IP	2010	2	3	X	X	X	X	O	O	O	3	X	X	X	O	O	O
Broadcast Voice	2	9	VDLm3	1	6	Voice	2015	1	3	X	X	X	X	O	O	O	2	X	X	X	O	O	X
Broadcast Voice	2	12	3G	1	7	IP	2020	3	3	X	X	X	X	O	O	O	2	X	X	X	X	O	O
Broadcast Voice	2	30	Airport Data Link	1	7	NA	2025	3	5	X	X	O	O	O	O	O	2	X	X	X	X	O	O
Broadcast Voice	2	16	Swift 64	1	7	IP	2005	1	1	X	X	X	X	X	X	O	1	X	X	X	O	X	X
Broadcast Voice	2	28	P-25	1	8	IP	2020	1	4	X	X	X	O	O	O	O	1	X	X	X	X	X	O
Broadcast Voice	2	19	SDLS	1	8	NA	2015	2	1	X	X	X	X	X	X	O	0	X	X	X	X	X	X
Broadcast Voice	2	21	Connexion by Boeing	2	9	IP	2005	3	3	O	O	X	X	X	X	O	1	X	X	X	O	X	X
Broadcast Voice	2	26	B-VHF	1	9	CLNP	2025	3	3	X	X	X	X	O	O	O	2	X	X	X	O	O	X
Broadcast Voice	2	27	B-VHF	1	9	IP	2025	3	3	X	X	X	X	O	O	O	2	X	X	X	O	O	X
Broadcast Voice	2	29	P-34	1	10	IP	2025	3	3	X	X	X	X	O	O	O	2	X	X	X	O	O	X

Table 13: Scenario 5 Data Services Coverage.

Service Class	Level	Comm. ID	Technology	Level	Total Cost	Year	Protocol	SWIM Support	Domain Holes	Gate	Surface	Terminal	Enroute	Remote	Oceanic	Polar	AirClass Holes	Transport	Cargo	Business Jet	GA	Military	UAV
Broadcast to Aircraft	2	23	1090-ES	1	1	2005	Layer-2	1	3	X	X	X	X	0	0	0	1	X	X	X	0	X	X
Broadcast to Aircraft	2	7	VDLm2	2	2	2005	NA	2	3	X	X	X	X	0	0	0	0	X	X	X	X	X	X
Broadcast to Aircraft	2	24	UAT	1	5	2010	Layer-2	2	4	0	X	X	X	0	0	0	4	0	0	X	X	0	0
Broadcast to Aircraft	2	18	SDARS	2	5	2015	IP	2	2	X	X	X	X	X	0	0	0	X	X	X	X	X	X
Broadcast to Aircraft	2	17	Swift Broadband	2	5	2010	IP	3	1	X	X	X	X	X	X	0	0	X	X	X	X	X	X
Broadcast to Aircraft	2	33	IEEE 802.16	1	6	2020	IP	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Broadcast to Aircraft	2	37	TETRA I/II	1	6	2025	IP	2	5	X	X	0	0	0	0	0	1	X	X	X	X	X	0
Broadcast to Aircraft	2	35	IEEE 802.20	2	6	2025	IP	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Broadcast to Aircraft	2	12	3G	1	7	2020	IP	3	3	X	X	X	X	0	0	0	2	X	X	X	X	0	0
Broadcast to Aircraft	2	30	Airport Data Link	1	7	2025	NA	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Broadcast to Aircraft	2	19	SDLS	2	8	2015	NA	2	1	X	X	X	X	X	X	0	0	X	X	X	X	X	X
Broadcast to Aircraft	2	27	B-VHF	1	9	2025	IP	3	3	X	X	X	X	0	0	0	2	X	X	X	0	0	X
Broadcast to Aircraft	2	29	P-34	1	10	2025	IP	3	3	X	X	X	X	0	0	0	2	X	X	X	0	0	X
Data Messaging	2	22	1090ES	2	1	2010	CLNP	1	4	0	X	X	X	0	0	0	1	X	X	X	0	X	X
Data Messaging	2	5	VDLm2	2	3	2010	CLNP	2	3	X	X	X	X	0	0	0	3	X	X	X	0	0	0
Data Messaging	2	17	Swift Broadband	1	5	2010	IP	3	1	X	X	X	X	X	X	0	0	X	X	X	X	X	X
Data Messaging	2	34	IEEE 802.16	1	6	2020	CNLP	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Data Messaging	2	37	TETRA I/II	1	6	2025	IP	2	5	X	X	0	0	0	0	0	1	X	X	X	X	X	0
Data Messaging	2	36	IEEE 802.20	1	6	2025	CLNP	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Data Messaging	2	8	VDLm3	1	6	2020	CLNP	2	3	X	X	X	X	0	0	0	2	X	X	X	0	0	X
Data Messaging	2	33	IEEE 802.16	1	6	2020	IP	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Data Messaging	2	35	IEEE 802.20	1	6	2025	IP	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Data Messaging	2	13	Aero-H	2	6	2005	ACARS	1	1	X	X	X	X	X	X	0	1	X	X	X	0	X	X
Data Messaging	2	12	3G	1	7	2020	IP	3	3	X	X	X	X	0	0	0	2	X	X	X	X	0	0
Data Messaging	2	30	Airport Data Link	1	7	2025	NA	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Data Messaging	2	14	Aero-H	2	7	2010	CLNP	1	1	X	X	X	X	X	X	0	1	X	X	X	0	X	X
Data Messaging	2	19	SDLS	1	8	2015	NA	2	1	X	X	X	X	X	X	0	0	X	X	X	X	X	X
Data Messaging	2	15	Aero-H	2	8	2010	IP	1	1	X	X	X	X	X	X	0	1	X	X	X	0	X	X
Data Messaging	2	27	B-VHF	1	9	2025	IP	3	3	X	X	X	X	0	0	0	2	X	X	X	0	0	X
Data Messaging	2	26	B-VHF	1	9	2025	CLNP	3	3	X	X	X	X	0	0	0	2	X	X	X	0	0	X
Data Messaging	2	29	P-34	1	10	2025	IP	3	3	X	X	X	X	0	0	0	2	X	X	X	0	0	X
Ground to Air Data	2	17	Swift Broadband	1	5	2010	IP	3	1	X	X	X	X	X	X	0	0	X	X	X	X	X	X
Ground to Air Data	2	33	IEEE 802.16	1	6	2020	IP	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Ground to Air Data	2	36	IEEE 802.20	1	6	2025	CLNP	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Ground to Air Data	2	34	IEEE 802.16	1	6	2020	CNLP	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Ground to Air Data	2	35	IEEE 802.20	1	6	2025	IP	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Ground to Air Data	2	30	Airport Data Link	1	7	2025	NA	3	5	X	X	0	0	0	0	0	2	X	X	X	X	0	0
Ground to Air Data	2	12	3G	1	7	2020	IP	3	3	X	X	X	X	0	0	0	2	X	X	X	X	0	0
Ground to Air Data	2	19	SDLS	1	8	2015	NA	2	1	X	X	X	X	X	X	0	0	X	X	X	X	X	X
Ground to Air Data	2	27	B-VHF	1	9	2025	IP	3	3	X	X	X	X	0	0	0	2	X	X	X	0	0	X
Ground to Air Data	2	26	B-VHF	1	9	2025	CLNP	3	3	X	X	X	X	0	0	0	2	X	X	X	0	0	X
Ground to Air Data	2	29	P-34	1	10	2025	IP	3	3	X	X	X	X	0	0	0	2	X	X	X	0	0	X

4.1.3 Scenario 10: Datalink to reduce routine workload.

The focus of this scenario is to move some of the analog voice communications to alternative communication links to relieve congestion in the VHF band. Table 14 and Table 15 give the voice service and data service coverage for this scenario respectively. The combination of 1090ES (CLNP), VDLm2 (CLNP), and SwiftBroadband for data messaging level 2 will provide coverage to all but the polar airspace sometime shortly after 2010.

Table 14: Scenario 10 Voice Services Coverage.

Service Class	Level	CommSys_ID	Technology	Level	Total Link Cost	Protocol	Year	SwimSupport	Domain Holes	Gate	Surface	Terminal	En Route	Remote	Oceanic	Polar	Airclass Holes	Transport	Cargo	Business Jet	GA	Military	UAV
Party Line Voice	3	1	VHF Analog Voice	1	3	NA	2005	0	3	X	X	X	X	0	0	0	0	X	X	X	NA	X	NA
Party Line Voice	3	17	Swift Broadband	3	5	IP	2010	3	1	X	X	X	X	X	X	0	0	X	X	X	NA	X	NA
Party Line Voice	3	37	TETRA I/II	1	6	IP	2025	2	5	X	X	0	0	0	0	0	0	X	X	X	NA	X	NA
Party Line Voice	3	35	IEEE 802.20	2	6	IP	2025	3	5	X	X	0	0	0	0	0	1	X	X	X	NA	0	NA
Party Line Voice	3	36	IEEE 802.20	2	6	CLNP	2025	3	5	X	X	0	0	0	0	0	1	X	X	X	NA	0	NA
Party Line Voice	3	34	IEEE 802.16	2	6	CNLP	2020	3	5	X	X	0	0	0	0	0	1	X	X	X	NA	0	NA
Party Line Voice	3	9	VDLm3	1	6	Voice	2015	1	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA
Party Line Voice	3	33	IEEE 802.16	2	6	IP	2020	3	5	X	X	0	0	0	0	0	1	X	X	X	NA	0	NA
Party Line Voice	3	30	Airport Data Link	2	7	NA	2025	3	5	X	X	0	0	0	0	0	1	X	X	X	NA	0	NA
Party Line Voice	3	12	3G	3	7	IP	2020	3	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA
Party Line Voice	3	19	SDLS	3	8	NA	2015	2	1	X	X	X	X	X	X	0	0	X	X	X	NA	X	NA
Party Line Voice	3	28	P-25	1	8	IP	2020	1	4	X	X	X	0	0	0	0	0	X	X	X	NA	X	NA
Party Line Voice	3	27	B-VHF	1	9	IP	2025	3	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA
Party Line Voice	3	26	B-VHF	1	9	CLNP	2025	3	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA
Party Line Voice	3	29	P-34	2	10	IP	2025	3	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA

Table 15: Scenario 10 Data Services Coverage.

Service Class	Level	Comm. ID	Technology	Level	Total Cost	Year	Protocol	SWIM Support	Domain Holes	Gate	Surface	Terminal	Enroute	Remote	Oceanic	Polar	AirClass Holes	Transport	Cargo	Business Jet	GA	Military	UAV
Data Messaging	2	22	1090ES	2	1	2010	CLNP	1	4	0	X	X	X	0	0	0	0	X	X	X	NA	X	NA
Data Messaging	2	5	VDLm2	2	3	2010	CLNP	2	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA
Data Messaging	2	17	Swift Broadband	1	5	2010	IP	3	1	X	X	X	X	X	X	0	0	X	X	X	NA	X	NA
Data Messaging	2	35	IEEE 802.20	1	6	2025	IP	3	5	X	X	0	0	0	0	0	1	X	X	X	NA	0	NA
Data Messaging	2	34	IEEE 802.16	1	6	2020	CNLP	3	5	X	X	0	0	0	0	0	1	X	X	X	NA	0	NA
Data Messaging	2	33	IEEE 802.16	1	6	2020	IP	3	5	X	X	0	0	0	0	0	1	X	X	X	NA	0	NA
Data Messaging	2	13	Aero-H	2	6	2005	ACARS	1	1	X	X	X	X	X	X	0	0	X	X	X	NA	X	NA
Data Messaging	2	8	VDLm3	1	6	2020	CLNP	2	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA
Data Messaging	2	37	TETRA I/II	1	6	2025	IP	2	5	X	X	0	0	0	0	0	0	X	X	X	NA	X	NA
Data Messaging	2	36	IEEE 802.20	1	6	2025	CLNP	3	5	X	X	0	0	0	0	0	1	X	X	X	NA	0	NA
Data Messaging	2	30	Airport Data Link	1	7	2025	NA	3	5	X	X	0	0	0	0	0	1	X	X	X	NA	0	NA
Data Messaging	2	14	Aero-H	2	7	2010	CLNP	1	1	X	X	X	X	X	X	0	0	X	X	X	NA	X	NA
Data Messaging	2	12	3G	1	7	2020	IP	3	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA
Data Messaging	2	15	Aero-H	2	8	2010	IP	1	1	X	X	X	X	X	X	0	0	X	X	X	NA	X	NA
Data Messaging	2	19	SDLS	1	8	2015	NA	2	1	X	X	X	X	X	X	0	0	X	X	X	NA	X	NA
Data Messaging	2	27	B-VHF	1	9	2025	IP	3	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA
Data Messaging	2	26	B-VHF	1	9	2025	CLNP	3	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA
Data Messaging	2	29	P-34	1	10	2025	IP	3	3	X	X	X	X	0	0	0	1	X	X	X	NA	0	NA

4.1.4 Scenario 15: Enhanced Emergency Alerting.

Table 16 shows the coverage table for scenario 15. The strict requirement for service level 1 Broadcast to Aircraft limits the number of candidate communication systems compared to early scenarios requiring the Broadcast to Aircraft service class. That being said, 1090-ES (Layer 2) in 2005 complemented by UAT sometime after 2010 will address all the communication needs of this scenario.

Table 16: Scenario 15 Data Services Coverage.

Service Class	Level	Comm. ID	Technology	Level	Total Cost	Year	Protocol	SWIM Support	Domain Holes	Gate	Surface	Terminal	Enroute	Remote	Oceanic	Polar	AirClass Holes	Transport	Cargo	Business Jet	GA	Military	UAV
Broadcast from Aircraft	1	23	1090-ES	1	1	2005	Layer-2	1	0	NA	NA	X	X	X	NA	NA	1	X	X	X	0	X	X
Broadcast from Aircraft	1	25	VDLm4	1	3	2010	CLNP	1	0	NA	NA	X	X	X	NA	NA	2	X	X	X	X	0	0
Broadcast from Aircraft	1	24	UAT	1	5	2010	Layer-2	2	0	NA	NA	X	X	X	NA	NA	4	0	0	X	X	0	0
Broadcast from Aircraft	1	12	3G	1	7	2020	IP	3	1	NA	NA	X	X	0	NA	NA	2	X	X	X	X	0	0
Broadcast from Aircraft	1	29	P-34	1	10	2025	IP	3	1	NA	NA	X	X	0	NA	NA	2	X	X	X	0	0	X

4.1.5 Scenario 20: Optimize Runway Assignments.

This is one of the more difficult scenarios as it requires three data service classes, each with relatively stringent service levels. Table 17 illustrates the coverage of the required service classes by the candidate communication systems. The limited applicability to airspace domain and aircraft class for this scenario allows for many different candidate links to address the communication requirements. As a result, 1090ES (layer 2 & CLNP), VDLm2 (CLNP), UAT, and Swift Broadband show up again as candidate links that will enable this scenario sometime soon after 2010.

Table 17: Scenario 20 Data Services Coverage.

Service Class	Level	Comm. ID	Technology	Level	Total Cost	Year	Protocol	SWIM Support	Domain Holes	Gate	Surface	Terminal	Enroute	Remote	Oceanic	Polar	AirClass Holes	Transport	Cargo	Business Jet	GA	Military	UAV
Broadcast from Aircraft	1	23	1090-ES	1	1	2005	Layer-2	1	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Broadcast from Aircraft	1	25	VDLm4	1	3	2010	CLNP	1	1	NA	0	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Broadcast from Aircraft	1	24	UAT	1	5	2010	Layer-2	2	0	NA	X	X	X	NA	NA	NA	2	0	0	X	NA	NA	NA
Broadcast from Aircraft	1	37	TETRA I/II	1	6	2025	IP	2	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Broadcast from Aircraft	1	33	IEEE 802.16	1	6	2020	IP	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Broadcast from Aircraft	1	12	3G	1	7	2020	IP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Broadcast from Aircraft	1	29	P-34	1	10	2025	IP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	17	Swift Broadband	1	5	2010	IP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	34	IEEE 802.16	1	6	2020	CNLP	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	36	IEEE 802.20	1	6	2025	CLNP	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	35	IEEE 802.20	1	6	2025	IP	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	33	IEEE 802.16	1	6	2020	IP	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	30	Airport Data Link	1	7	2025	NA	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	12	3G	1	7	2020	IP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	19	SDLS	1	8	2015	NA	2	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	26	B-VHF	1	9	2025	CLNP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	27	B-VHF	1	9	2025	IP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Ground to Air Data	2	29	P-34	1	10	2025	IP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	22	1090ES	2	1	2010	CLNP	1	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	5	VDLm2	2	3	2010	CLNP	2	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	17	Swift Broadband	1	5	2010	IP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	37	TETRA I/II	1	6	2025	IP	2	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	35	IEEE 802.20	1	6	2025	IP	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	8	VDLm3	1	6	2020	CLNP	2	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	13	Aero-H	2	6	2005	ACARS	1	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	34	IEEE 802.16	1	6	2020	CNLP	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	36	IEEE 802.20	1	6	2025	CLNP	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	33	IEEE 802.16	1	6	2020	IP	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	12	3G	1	7	2020	IP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	30	Airport Data Link	1	7	2025	NA	3	2	NA	X	0	0	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	14	Aero-H	2	7	2010	CLNP	1	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	19	SDLS	1	8	2015	NA	2	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	15	Aero-H	2	8	2010	IP	1	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	27	B-VHF	1	9	2025	IP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	26	B-VHF	1	9	2025	CLNP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA
Trajectory Exchange	2	29	P-34	1	10	2025	IP	3	0	NA	X	X	X	NA	NA	NA	0	X	X	X	NA	NA	NA

4.1.6 Scenario 25: Controller awareness of TCAS resolutions.

Table 18 shows the coverage holes for Scenario 25, “Controller awareness of TCAS resolutions”. This scenario requires the data messaging service class with a stringent service level requirement. This dramatically limits the possible candidate links, introducing significant coverage holes in the Remote, and Oceanic airspace domains without the use of satellites. Also notice that none of the candidate links meet the coverage requirements in the polar domain and earliest available is in 2010, Swift Broadband.

Table 18: Scenario 25 Data Services Coverage.

Service Class	Level	Comm. ID	Technology	Level	Total Cost	Year	Protocol	SWIM Support	Domain Holes	Gate	Surface	Terminal	Enroute	Remote	Oceanic	Polar	AirClass Holes	Transport	Cargo	Business Jet	GA	Military	UAV
Data Messaging	1	17	Swift Broadband	1	5	2010	IP	3	1	NA	NA	X	X	X	X	O	0	X	X	X	NA	X	X
Data Messaging	1	8	VDLm3	1	6	2020	CLNP	2	3	NA	NA	X	X	O	O	O	1	X	X	X	NA	O	X
Data Messaging	1	12	3G	1	7	2020	IP	3	3	NA	NA	X	X	O	O	O	2	X	X	X	NA	O	O
Data Messaging	1	19	SDLS	1	8	2015	NA	2	1	NA	NA	X	X	X	X	O	0	X	X	X	NA	X	X
Data Messaging	1	26	B-VHF	1	9	2025	CLNP	3	3	NA	NA	X	X	O	O	O	1	X	X	X	NA	O	X
Data Messaging	1	27	B-VHF	1	9	2025	IP	3	3	NA	NA	X	X	O	O	O	1	X	X	X	NA	O	X
Data Messaging	1	29	P-34	1	10	2025	IP	3	3	NA	NA	X	X	O	O	O	1	X	X	X	NA	O	X

4.1.7 Scenario 29: Aircraft push of security video and aircraft performance during emergency.

This scenarios was defined during GCNSS I in response to the events that transpired within the NAS on September 11, 2001. It includes requirements for downlink of video, aircraft state (ADS), and other cockpit information. Table 19 shows the communication system coverage for the different required communication services for this scenario. Again, 1090ES (Layer 2) and Swift Broadband can meet most of the requirements for this scenario in all airspace domains except Polar. In Gate, Surface, Terminal, and En Route this scenario could be supported sometime soon after the year 2010.

There is an issue regarding broadcast from aircraft in the Remote and Oceanic airspace domains. SwiftBroadband is currently defined to provide only level 3 Broadcast from Aircraft while the terrestrial based systems cannot provide coverage in these domains. This suggests that a reduced functionality version of this scenario would be applicable in these domains. It would still provide video and downlink of cockpit information with a slight degradation in the service quality of the aircraft state information.

Table 19: Scenario 29 Data Services Coverage.

Service Class	Level	Comm. ID	Technology	Level	Total Cost	Year	Protocol	SWIM Support	Domain Holes	Gate	Surface	Terminal	Enroute	Remote	Oceanic	Polar	AirClass Holes	Transport	Cargo	Business Jet	GA	Military	UAV
Air to Ground Data	2	17	Swift Broadband	1	5	2010	IP	3	1	X	X	X	X	X	X	O	0	X	NA	NA	NA	NA	NA
Air to Ground Data	2	36	IEEE 802.20	1	6	2025	CLNP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Air to Ground Data	2	35	IEEE 802.20	1	6	2025	IP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Air to Ground Data	2	33	IEEE 802.16	1	6	2020	IP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Air to Ground Data	2	34	IEEE 802.16	1	6	2020	CNLP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Air to Ground Data	2	30	Airport Data Link	1	7	2025	NA	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Air to Ground Data	2	12	3G	1	7	2020	IP	3	3	X	X	X	X	O	O	O	0	X	NA	NA	NA	NA	NA
Air to Ground Data	2	19	SDLS	1	8	2015	NA	2	1	X	X	X	X	X	X	O	0	X	NA	NA	NA	NA	NA
Air to Ground Data	2	27	B-VHF	1	9	2025	IP	3	3	X	X	X	X	O	O	O	0	X	NA	NA	NA	NA	NA
Air to Ground Data	2	26	B-VHF	1	9	2025	CLNP	3	3	X	X	X	X	O	O	O	0	X	NA	NA	NA	NA	NA
Air to Ground Data	2	29	P-34	1	10	2025	IP	3	3	X	X	X	X	O	O	O	0	X	NA	NA	NA	NA	NA
Broadcast from Aircraft	2	23	1090-ES	1	1	2005	Layer-2	1	3	X	X	X	X	O	O	O	0	X	NA	NA	NA	NA	NA
Broadcast from Aircraft	2	25	VDLm4	1	3	2010	CLNP	1	5	O	O	X	X	O	O	O	0	X	NA	NA	NA	NA	NA
Broadcast from Aircraft	2	36	IEEE 802.20	2	6	2025	CLNP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Broadcast from Aircraft	2	33	IEEE 802.16	1	6	2020	IP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Broadcast from Aircraft	2	35	IEEE 802.20	2	6	2025	IP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Broadcast from Aircraft	2	37	TETRA I/II	1	6	2025	IP	2	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Broadcast from Aircraft	2	12	3G	1	7	2020	IP	3	3	X	X	X	X	O	O	O	0	X	NA	NA	NA	NA	NA
Broadcast from Aircraft	2	29	P-34	1	10	2025	IP	3	3	X	X	X	X	O	O	O	0	X	NA	NA	NA	NA	NA
Video Exchange	2	17	Swift Broadband	2	5	2010	IP	3	1	X	X	X	X	X	X	O	0	X	NA	NA	NA	NA	NA
Video Exchange	2	35	IEEE 802.20	2	6	2025	IP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Video Exchange	2	36	IEEE 802.20	2	6	2025	CLNP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Video Exchange	2	34	IEEE 802.16	1	6	2020	CNLP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Video Exchange	2	33	IEEE 802.16	1	6	2020	IP	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Video Exchange	2	30	Airport Data Link	1	7	2025	NA	3	5	X	X	O	O	O	O	O	0	X	NA	NA	NA	NA	NA
Video Exchange	2	12	3G	2	7	2020	IP	3	3	X	X	X	X	O	O	O	0	X	NA	NA	NA	NA	NA
Video Exchange	2	21	Connexion by Boeing	2	9	2005	IP	3	3	O	O	X	X	X	X	O	0	X	NA	NA	NA	NA	NA
Video Exchange	2	29	P-34	2	10	2025	IP	3	3	X	X	X	X	O	O	O	0	X	NA	NA	NA	NA	NA

4.1.8 Scenario 32: Push of Security advisories to aircraft.

This is another security based scenario that involves pushing of security advisories to aircraft during events like those that occurred on September 11th, 2001. It would require Data Messaging with a service level of 2. Again, a combination of 1090ES (CLNP), VDLm2 (CLNP), and Swift Broadband could begin handling this scenario sometime shortly after 2010.

Table 20: Scenario 32 Data Services Coverage.

Service Class	Level	Comm. ID	Technology	Level	Total Cost	Year	Protocol	SWIM Support	Domain Holes	Gate	Surface	Terminal	Enroute	Remote	Oceanic	Polar	AirClass Holes	Transport	Cargo	Business Jet	GA	Military	UAV
Data Messaging	2	22	1090ES	2	1	2010	CLNP	1	4	O	X	X	X	O	O	O	1	X	X	X	O	X	X
Data Messaging	2	5	VDLm2	2	3	2010	CLNP	2	3	X	X	X	X	O	O	O	3	X	X	X	O	O	O
Data Messaging	2	17	Swift Broadband	1	5	2010	IP	3	1	X	X	X	X	X	X	O	0	X	X	X	X	X	X
Data Messaging	2	34	IEEE 802.16	1	6	2020	CNLP	3	5	X	X	O	O	O	O	O	2	X	X	X	X	O	O
Data Messaging	2	37	TETRA I/II	1	6	2025	IP	2	5	X	X	O	O	O	O	O	1	X	X	X	X	X	O
Data Messaging	2	36	IEEE 802.20	1	6	2025	CLNP	3	5	X	X	O	O	O	O	O	2	X	X	X	X	O	O
Data Messaging	2	8	VDLm3	1	6	2020	CLNP	2	3	X	X	X	X	O	O	O	2	X	X	X	O	O	X
Data Messaging	2	33	IEEE 802.16	1	6	2020	IP	3	5	X	X	O	O	O	O	O	2	X	X	X	X	O	O
Data Messaging	2	35	IEEE 802.20	1	6	2025	IP	3	5	X	X	O	O	O	O	O	2	X	X	X	X	O	O
Data Messaging	2	13	Aero-H	2	6	2005	ACARS	1	1	X	X	X	X	X	X	O	1	X	X	X	O	X	X
Data Messaging	2	12	3G	1	7	2020	IP	3	3	X	X	X	X	O	O	O	2	X	X	X	X	O	O
Data Messaging	2	14	Aero-H	2	7	2010	CLNP	1	1	X	X	X	X	X	X	O	1	X	X	X	O	X	X
Data Messaging	2	30	Airport Data Link	1	7	2025	NA	3	5	X	X	O	O	O	O	O	2	X	X	X	X	O	O
Data Messaging	2	19	SDLS	1	8	2015	NA	2	1	X	X	X	X	X	X	O	0	X	X	X	X	X	X
Data Messaging	2	15	Aero-H	2	8	2010	IP	1	1	X	X	X	X	X	X	O	1	X	X	X	O	X	X
Data Messaging	2	27	B-VHF	1	9	2025	IP	3	3	X	X	X	X	O	O	O	2	X	X	X	O	O	X
Data Messaging	2	26	B-VHF	1	9	2025	CLNP	3	3	X	X	X	X	O	O	O	2	X	X	X	O	O	X
Data Messaging	2	29	P-34	1	10	2025	IP	3	3	X	X	X	X	O	O	O	2	X	X	X	O	O	X

4.2 REPRESENTATIONAL TRANSITION PLANS

In this section, the information presented in earlier sections is aggregated to provide a high level look at possible transition plans for each of the eight operational scenarios described earlier. Recall, these scenarios were selected for having high benefit for low risk which tended to highlight scenarios that are candidates for early deployment. The diagrams in the sections below illustrate the mapping of communication systems to communication service classes (including service levels) which in turn support operational scenarios. Over time as new communication systems become available they extend coverage of existing communication services or enable new communication service classes and/or levels that in turn meet the needs of additional operational scenarios. The diagrams were developed with the simple assumption that 2.5 years after the arrival of a candidate link the communications services that it supports are available to aircraft. This lag would be expected for such things as certification and equipage of aircraft. Also, there is a delay of less than 2.5 years between when an all the communication services required for a scenario are supported and when the scenario itself becomes supported. This accounts for the slow roll out of scenarios with mostly likely it beginning in limited areas. These values were chosen quickly and there is room for refinement. In addition it is unlikely these lags would be the same for all communication services and operational scenarios. Most, likely there would be some variation between them depending on the communication service and the complexity of the operational scenario. The scenarios, systems, and services are referenced by labels whose definitions are given in section 2. Detailed descriptions of these scenarios, systems, and services are found in the MCNA Requirement Report, [1], and the MCNA Architecture Report, [2].

The focus of these transition plans was on early deployment of MCNA enabled operational scenarios. For this reason the timeline explored was limited from present day until 2015. The communication systems that were selected for the analysis were those with the earliest deployment, lowest total cost, and coverage of the most operational scenarios.   Most communication links, besides SwiftBroadband, are not the best for support of SWIM. This is based many only their limited support of IP protocol. This means they do not have sufficient functionality to be considered part of the Common Data Transport (CDT). This does not mean that the operational scenarios that they support are completely orthogonal to SWIM and NEO. Instead it reflects the transition implementation concepts put forward in section 3.1.1 where initially SWIM nodes reside on the ground and gateways are used to bridge the gap between the SWIM and applications running on hosts on the aircraft.   These SWIM aircraft node transition concepts are discussed in detail in section 3.3 of the MCNA Architecture Report.

4.2.1 Safety and Security Scenarios

Figure 6 illustrates the transition plan diagram for the safety and security scenarios (Scenarios #15, #25, #29, and #32).   Scenario #15 (Enhanced Emergency Alerting) only requires Broadcast from Aircraft Level 1 (BFA1) and can begin before 2010 using 1090ES (layer 2) for all aircraft classes besides GA. In 2010 as UAT becomes available this operation scenario coverage extends to GA.

Scenario #25 (Controller awareness of TCAS resolutions) only requires Data Messaging Level 1 but it is not until SwiftBroadband arrives in the 2010 timeframe that this communication service becomes available. This would suggest this scenario could be supported sometime before 2015.

Scenario #29 (Aircraft push of security video and aircraft performance during emergency) requires three different data communication services. While Broadcast from Aircraft Level 2 is possible in the near future, Video Exchange Level 2 and Air to Ground Data Level 2 is not available until after 2010 via Swift Broadband, VDLm2 (CLNP), or 1090ES (CLNP).   This could probably be pushed forward in time by using other satellite or terrestrial based communication services for Video Exchange 2 and using another service other than Air to Ground Level 2 (which implies SWIM).

Scenario #32 (Push of Security advisories to aircraft) only requires Data Messaging Level 2 which is currently provided by Aero-H (data 2, ACARS).   This provides coverage to properly equipped aircraft until 2010 when VDLm2 (CLNP), Swift Broadband, and 1090ES (CLNP) should be available to extend the coverage of Data Messaging Level 2 to more aircraft.

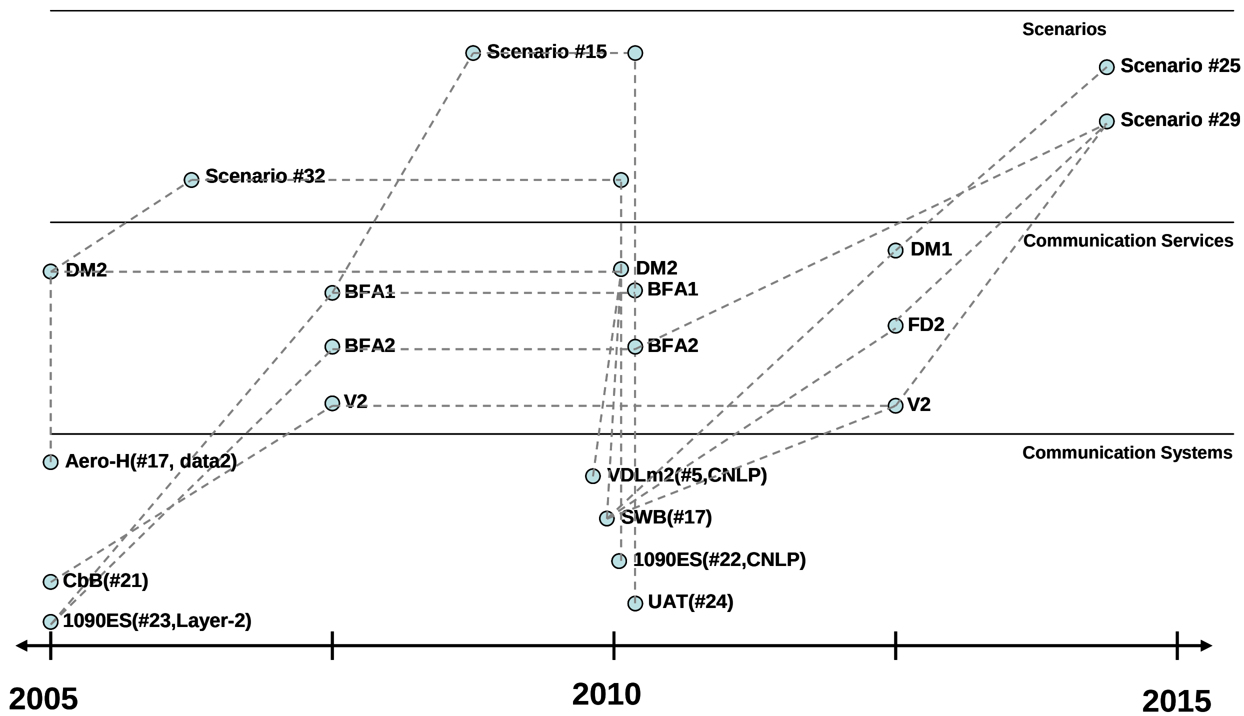

Figure 6: Safety and Security Scenarios Transition Diagram.

4.2.2 Flight Objects and AIM Scenarios

These scenarios deal with flight objects and aeronautical information management scenarios. Again, several of them provide early opportunities within the 2005-2010 timeframe. Figure 7 below shows the transition plan diagram for these operational scenarios.

Scenario #1 (Deploy FIS-B Nationally) requires the least stringent Broadcast to Aircraft service level. Initially, this can be provided by VDLm2 (VDL-B) and 1090ES (Layer 2). In the 2010 timeframe this can be supplemented with Swift Broadband and UAT.

Scenario #10 (Datalink to reduce routine workload) requires the least stringent Data Messaging service level and party line voice service level 3. In the near term, this can be provided through aircraft equipped with Aero-H for the data service and through current VHF analog voice service. Later, near 2010, this can be supplemented with VDLm2 (CLNP), Swift Broadband, and 1090ES (CLNP). These additional candidate links will extend the coverage to more aircraft; those equipped for any of these candidate links. In addition, the option of using any of these candidates links provide the potential of cost savings to the FAA and airlines through reduced equipage, service, and maintenance costs.

Scenario #20 (Optimize Runway Assignments) is deferred until after 2010 because it requires Trajectory Exchange 2 and Air to Ground Data 2 which are not available until VDLm2 (CLNP), SwiftBroadband, and 1090ES (CLNP) are deployed.

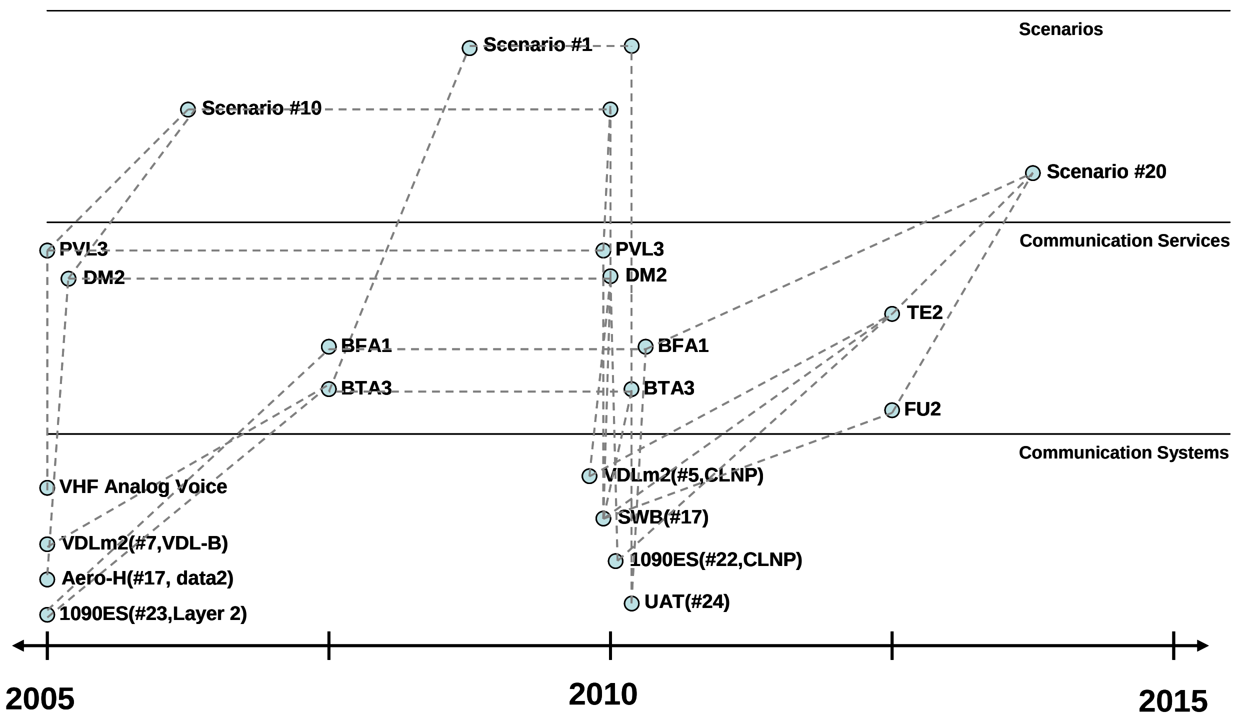

Figure 7: Flight Objects and AIM Scenarios Transition Diagram.

4.2.3 Weather and Surveillance Scenarios

The relatively relaxed communication service requirements associated with Weather and Surveillance related operational scenarios provide opportunities for support before 2010, Figure 8. Scenario #1 (Deploy FIS Nationally) is applicable to this section but the description in the previous section will suffice.

Recall that Scenario #5 (Autonomous Hazard Weather Alert Notification) is special in that it requires any of four different voice and data communication services to meet its communication service needs. Broadcast voice can begin this scenario immediately in all airspace domains but remote, oceanic, and polar. Also in the near term Broadcast to Aircraft level 2 could support this scenarios using VDLm2 (VDL-B) and 1090ES (Layer 2). In 2010 and beyond, this scenario could be supported by VDLm2 (CLNP), SwiftBroadband, 1090ES (CLNP) and UAT through Broadcast to Aircraft Level-2, Data Messaging Level-2, or Ground to Air Level-2.

Scenario #15 (Enhanced Emergency Alerting) is also another repeat and is discussed in section 4.2.1 above.

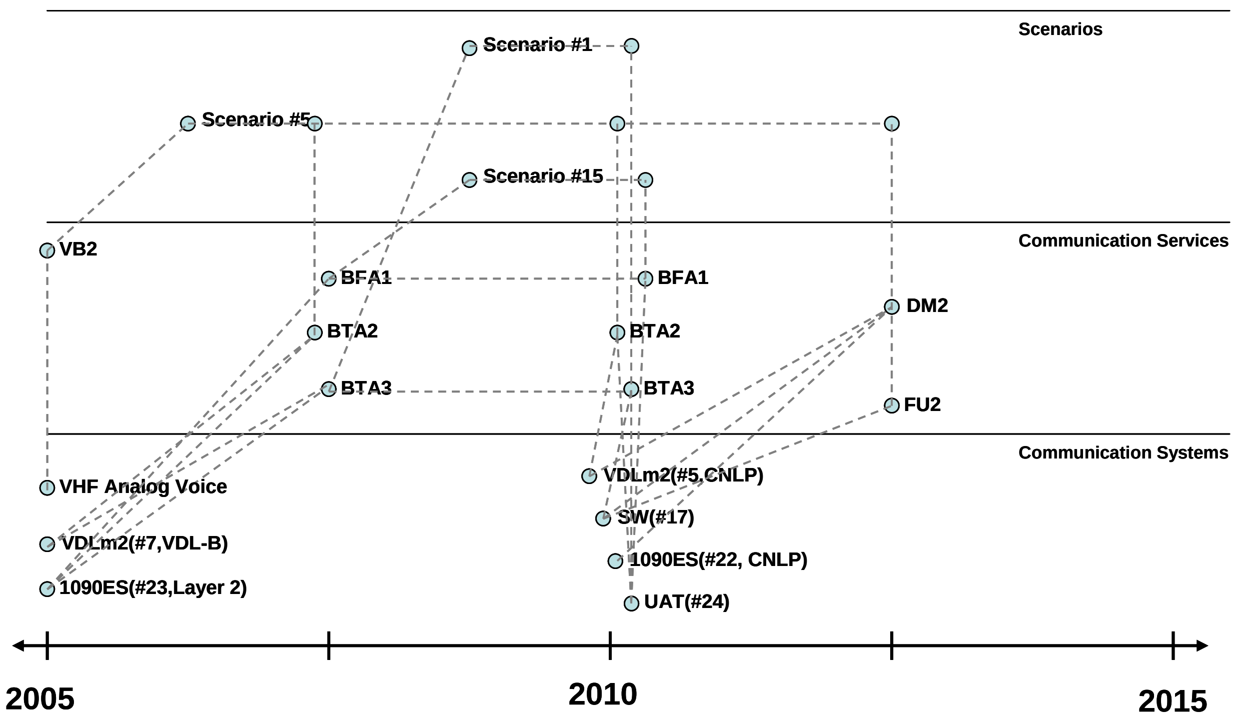

Figure 8: Weather and Surveillance Scenarios Transition Diagram

4.3 COMPARISON OF MCNA TO TSD (2015)

The current projection of the state of the NAS architecture in 2015 is described in the FAA's Target System Description (TSD), [10][11]. This section highlights the departure of MCNA from the TSD.

The current communications links that are fully operationally employed by the FAA include the following:

- NAS Domestic
  - VHF Analog Voice
  - POA (ACARS)
  - AOA (ACARS) (which in Table 6 is called VDLm2 (ACARS))
- Oceanic
  - HF Voice
  - HFDL (ACARS)
  - Aero-H SatCom (ACARS)

The Target System Description (TSD) aims to introduce the following communication links by 2015. [9] [10]

- NAS Domestic

        - **VDLm3 Voice**
        - **VDLm3 Data (CLNP)**
        - VDLm2 (CLNP)
        - UAT (ADS-B)
        - 1090-ES (ADS-B)
    - Oceanic
        - HFDL (CLNP)

The VDLm3 services are identified in **RED** and **BOLD** because the CATS-I database shows the rollout of these communication links just starting in 2015.

There are significant differences when compared to the MCNA assumptions for communication links available in 2015. These were highlighted in the previous sections as the technologies that would enable the chosen operational scenarios as soon as possible. Mostly additional candidate links are integrated with those of the TSD to provide higher service levels and more service classes. The largest difference is the omission of VDLm3 in the MCNA 2015 vision.

- NAS Domestic
    - VHF Analog Voice (8.33kHz)
    - VDLm2 (CLNP)
    - VDL-B (Broadcast)
    - UAT (ADS-B)
    - 1090-ES (ADS-B)
    - 1090-ES (CLNP)
    - Swift Broadband
    - Connexions by Boeing
- Oceanic
    - Swift Broadband
    - Connexions by Boeing

Table 21 shows the comparison of the risk in supporting the operational scenarios for the TSD and various timeframes of MCNA. The MCNA 2015 strategy includes additional communication systems that lower the risk of being able to support the chosen operational scenarios.

Table 21: Comparison of MCNA and TSD.

Scenario	Communication Services: Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trijaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control	2005	TSD 2015	MCNA 2015	MCNA 2025
Deploy FIS-B Nationally						3										
Autonomous Hazard Weather Alert Notification			2	2		2		2								
Datalink to reduce routine workload	3			2												
Enhanced Emergency Alerting							1									
Optimize Runway Assignments					2		1	2								
Controller awareness of ACAS resolutions				1												
Aircraft push of security video and aircraft performance during emergency							2		2		1					
Push of Security advisories to aircraft				2												

5 MCNA INTEROPERABILITY ISSUES

One of the key components of the MCNA vision is the seamless interoperability of many heterogeneous communication links, networks, and systems to offer an integrated communication architecture capable of a wide range of enhanced communication services. The basic idea being that the whole is greater than the sum of the parts. To that end, it is important to address those interoperability issues and related pitfalls that will impede this goal of a seamlessly integrated communication architecture.

This section addresses the interoperability issues of MCNA architectural, topology and transition strategies. The topics are covered at a high level and are not meant to be an exhaustive treatment of these issues. Most are dealt with in much more detail in the deliverables of the other MCNA subtask, [1][2][3][4].

5.1 POLITICAL AND ECONOMIC

Aircraft, ground, and A/G systems can evolve independently but they provide no user benefit without complementary enhancements to the peer systems. Air traffic service providers do not realize any benefit until the number of airspace users attains critical mass. On the other hand, aircraft operators, OEM and equipment manufacturers remain unmotivated to develop and install certification-dependent ATC functions until terrestrial supporting facilities are widely deployed and benefits are easily derived. In turn, this infrastructure must enable operational changes that improve the cost, efficiency, and capacity of the ATC system and aircraft operators. This interdependency can result in a deadlock and inaction if each stakeholder waits for other entities to take the first step. Therefore, it is essential that all stakeholders commit to technology investments with a common objective that leads to defined benefits. To facilitate stakeholder commitments, an MCNA technology roadmap [3] with incremental steps was developed as part of the MCNA effort to achieve this end objective. Ideally, each incremental step should provide sufficient benefits for the level of investment. Once the roadmap is defined, both aircraft operators and ATS provider should make firm commitment to perform lockstep enhancements. Cost/benefit tradeoff may not be the deciding factor for investment in NAS modernization. Aircraft equipage, on the other hand, is heavily influenced by return on investment with expected breakeven in 18 to 24 months or less, Therefore, if an incremental step does not yield sufficient benefit for the aircraft operator, the ATS provider may mandate the required capabilities or provide financial incentives to facilitate equipage. In the absence of quantifiable benefits for the aircraft operators, incentives would be the preferred option for financially strapped US air carriers.

5.2 NETWORK PROTOCOL STACK

One key aspect of the aviation communications environment that greatly complicates the MCNA is the simultaneous existence three different networking protocols: ACARS, ATN and IP ACARS is the predominant technology for ATS datalink and is used in the FANS 1/A system that provides service to thousands of aircraft but plans are currently being implemented to supplant ACARS with ATN. However, it has experienced extensive deployment delays and airline resistance. Regardless, ATN deployment is underway in Europe even though the ATN SARPS are still undergoing revision to define additional functionality such as security. IP is the dominant world standard for information technology. As a result, it is slowly gaining acceptance within the aviation community as the likely end-state networking protocol. However, the IP protocol stack has key deficiencies that must be addressed to accommodate the requirement defined for ATN. Currently IP does not have any mechanisms for mobility that are inherent in the ATN protocol. Furthermore, the Internet Engineering Task Force (IETF) is actively engaged in multiple research and development efforts to address each of the identified shortcomings of the IP protocols (mobility, multihoming, policy based routing) as related to the support of aeronautical communications. In the transition period to the MCNA vision all of these protocols will have to be supported, sometimes simultaneously. All of these protocols have different (if any) mechanisms for achieving the network functionality required for MCNA. These include routing, mobility, multihoming, policy based routing, multicast, QoS, Security, and Network Management. The MCNA Architecture Document [2] discusses these issues in detail and proposes methodologies of how the MCNA will support all possibilities.

In most cases, an application on the aircraft will be associated with a single network protocol while the available air-ground links relate to multiple network protocols. Consequently, it will be necessary for there to be accommodation between network protocols. Three different mechanisms were evaluated in the MCNA architecture subtask for this purpose; message tunneling, network tunneling and parallel networks. Parallel network means that a given candidate link is either capable of or modified to support additional network protocols. Technically, parallel networks are ideal. However, the cost to deploy ACARS, ATN and IP networks to all of the VHF ground stations (for example) may prove cost restrictive. Network tunneling treats a connection through one network as a logical datalink connection for another network. This approach can reduce cost, but results in the application of redundant headers and the associated overhead and latency. The third accommodation mechanism under consideration is application messaging. This is a preferred alternative as there is already the intention to use message routing as a means to integrate with SWIM and resolve the mobility, multihoming and PBR requirements for near term IP. Since most of the communication application are message-based, a message routed infrastructure could be employed that is network protocol independent.

In addition to the different networking protocols there will also be communication links that are not designed to support any standard network protocol stack. One example is the systems designed to support digital voice. These are circuit based solutions that are optimized for latency and bandwidth efficiency of voice traffic. In the data services there are communication technologies that were designed for broadcast services that generally do not support a full network protocol stack. These system omit many of the higher layers of the protocol stack to increase bandwidth efficiency. These include VDL-B and some of the other technologies that will support FIS-B and TIS-B services. Also, UAT and 1090ES ADS-B systems squeeze most of the higher network layers into network layer 2. These will have to be considered in the overall MCNA system. This means that although the final goal is for a portion of the MCNA to be CDT compliant and fully support SWIM, the Vision MCNA will need to support multiple protocol stacks.

5.3 CERTIFICATION

All avionics need to be certified for airworthiness before they can be installed on an aircraft. The level and complexity of the certification process depend on the criticality of the function performed by the airborne system. It is relatively simple to get commercial systems approved for non-essential functions. This is frequently accomplished at present. A major goal of the vision state of MCNA is to leverage commercial networks and products, but it is unclear how to satisfy the certification requirements for ATM. The MCNA Certification Report [CDRL A047] [4] provides an overview of the system, avionics, and aircraft certification process and associated issues and risks.

The main issue is that there is currently no FAA acknowledged process in place by which a commercial system or the avionics suitable for use with a commercial system can be approved for the transmission of safety services, including both ATS and AOC services. Current commercial systems and their corresponding avionics used for these purposes have been approved and/or developed in an *ad hoc* manner appropriate to the needs of the community at the times of their development. There is, however, a *model* for the information required and the methodology by which that information could be developed. This model is contained in DO-270 [12]. The recommendation coming out of the certification subtask was that a cooperative effort between FAA and interested parties should be undertaken to develop and approve an agreed-upon process for the submission and review of relevant data and the approval of commercial services and their avionics for AOC and ATS applications. This would need to include the approval of the commercial terrestrial telecommunications infrastructure of these systems for safety information.

Lastly, there was an additional recommendation that a cooperative effort between FAA and interested parties, possibly including the efforts of RTCA Special Committees, should be undertaken to develop details of how RCP could be applied on an aircraft-by-aircraft basis, with the goal of simplifying or reducing aircraft equipage. The role of software defined radios should be considered within this context.

5.4 AVIONICS AND AIRCRAFT NETWORKS

Today the avionics architecture for commercial aircraft is a federated communication architecture. The various communication capabilities are handled using dedicated hardware devices. For the MCNA vision, where each aircraft can support numerous different communication links, this can create cost issues related to operation, implementation, maintenance, and logistics. Fortunately, with technological advancements, the avionics industry is driving towards more integration among subsystems. This trend relies on software defined functions over a limited number of common hardware platforms. Using groups of common components, each platform is programmed differently via software. These issues are addressed in detail in section 4 of the MCNA Architecture Report, [2].

Digital signal processing (DSP) hardware permit further integration of communication and navigation transceivers through software defined radios (SDRs). The SDRs use the same software components but exercise different configuration parameters to provide different communication, navigation, and surveillance (CNS) capability. This software-defined radio concept is implemented in ARINC 750 complient VDRs. The SDR trend will continue in future where a single LRU will be dynamically reconfigured to perform one or more CNS radio functions. Since the SDR utilizes common hardware and software-defined components, it lowers development, integration, logistics, operational and maintenance cost. Overall system availability may be improved at a lower cost by leveraging *n-of-m* redundancy of system components. By appropriate design of the common hardware and software elements, the integrated SDR architecture may acquire certification credit due to reuse. One major concern of reuse is that it may introduce a single point of failure, where a common hardware component failure or software component error affects multiple functions. Current safety-critical architectures often use "dual-dissimilar" designs, where the critical function is implemented in independent hardware using different implementation designs. In an SDR architecture, safety-critical functions that require very high integrity might still drive towards dissimilar implementations to reduce the probability of multiple subsystem failures arising from a common cause.

ARINC Aircraft Data Network (ADN) Specification 664 applies commercial IETF standards to aircraft and air/ground data networking to achieve network centric airline operations. The ADN uses a domain model to differentiate aircraft functions according to their criticality to ensure flight and passenger safety. This approach permits adaptation of the IETF standards according to the criticality of the functions while limiting the number of alternatives to maximize interoperability and reduce implementation costs.

The domain model consists of four domains. The Aircraft Control Domain (ACD) has highest level of criticality and contains the Flight and Embedded Control Sub-domain and the Cabin Core Sub-domain that support safety-critical services. The Airline Information Services Domain (AISD) contains the administrative, flight support and maintenance support functions for the flight deck and the cabin. This domain handles less critical information than ACD. At the lowest level are the Passenger Information and Entertainment Services Domain (PIESD) and the Passenger Owned Devices Domain (PODD) that support passenger entertainment and productivity.

On board networks within ACD and AISD can be implemented as either one physically integrated network or two different physically-separate networks. Having physical separation simplifies security and protection rules to be applied. In addition, it may reduce cost of certification and upgrades. On the other hand, having one fully integrated network can improve the overall system maintainability and logistics as well as reduce installation cost. However, an integrated network may impose extra cost of upgraded certification of all AISD devices and applications from DO-178B level D to, potentially, DO-178B level A. The increased requirements come about because these devices may interact with flight-critical devices within the ACD. A thorough cost/benefit study is needed to address the tradeoff between these two architectural implementations. The conclusion of this study should give us a better insight of the probable implementation approach for the 2015-2020 timeframe.

5.5 FTI

As an extension of the CDT, the MCNA should be fully compatible with FTI, to support SWIM and NCO. Since MCNA services will integrate with FTI services to create end-end communications services, it would be advisable to integrate the network management functions.

Given that the FTI NOCCs and NMO functionality are already established, it would make sense to leverage and augment this capability as applicable to meet the unique needs of MCNA. However, more research is required to investigate design alternatives and assure compliance with FTI terrestrial IP network design.

Acknowledging that MCNA will need to interface with FTI, the MCNA multicast architecture will need to be compatible with FTI multicast. This should not be a significant coordination effort given that IP multicast is fairly standard and the Layer-2/Layer-3 multicast interface for which we are concerned is implemented at the access routers which would typically be within the domain of MCNA rather than FTI. However, specific IP multicast protocols such as PIM-SM and BGMP should be coordinated. At this time our access to specifics about FTI is limited. However, given our knowledge of the transition plan for FTI, it is anticipated that IP multicast considerations will be addressed at later stage of that program.

The QoS architecture, particularly for both the near term and far term IP solutions must be compatible with FTI. Given the limited availability of detailed technical information on FTI, this will need to be the subject of future research activities. SWIM is concerned with QoS both from the perspective of data transport and message handling. As such, SWIM will rely upon QoS mechanisms provided by FTI and MCNA but also introduce QoS mechanisms at higher layers to assure that information request are addressed in the appropriate order. In the case of the near term IP architecture, additional overlap may exist between the MCNA and SWIM QoS architectures. In particular, the SWIM message routing function employed by MCNA will likely introduce message header fields and associated message queue servicing algorithms. MCNA will need to conduct research to determine if these application layer QoS facilities should be employed and if they are what QoS interaction consideration must be addressed.

Network security mechanisms for MCNA should be consistent with the FTI security architecture. At this time, our limited exposure to FTI architectural information prevents us from commenting on the degree to which this is currently coordinated. A recommended action for future MCNA development would be assuring such coordination.

In order to support FAA safety services, the FAA requires the development of several security documents. One of these documents is the Protection Profile (PP). An MCNA Protection Profile would be based upon the High Risk NAS WAN PP Template. This should be the same as the FTI PP. The FAA has already created templates for these documents. Therefore, the effort required to develop an MCNA PP would simply entail minor modification of the appropriate template (mentioned above) with descriptive information about MCNA.

6 CONCLUSIONS AND RECOMMENDATIONS

This document presented concepts for the transition from today's disparate communication systems with uneven coverage and insufficient capabilities toward a single integrated Mobile Communication Network Architecture that will support System Wide Information Management (SWIM) and Network Centric Operations (NCO). The transition analysis was driven by the MCNA operational scenario selected as part of the requirements analysis and the candidate link selection that was part of the MCNA architecture subtask. Eight scenarios were chosen based on favorable ratio of benefit to risk. The thirty seven candidate communication links were based on an expanded set of those considered in Future Communication System (FCS) Technology Pre-screening study [6].

The focus of the transition analysis was on supporting the selected operational scenarios in the near to mid term. The transition analysis indicated that the majority of the operational scenarios could be fully supported before 2015. In fact, those that do not involved safety of life communications could be supported before 2010. The only significant shortfall was providing communication services needed for some of scenarios in the polar airspace domain.

The subset of candidate links that came out of the transition analysis included some commercial satellite communication systems that are not certified for safety services. Connexions by Boeing arose one of the systems that could provide the video exchange service class for the scenario "Aircraft push of security video and aircraft performance during emergency". Swift Broadband, arriving in the 2010 timeframe, could support the communication service requirements of many of the chosen operational scenarios. The coverage capabilities make it very well suited for the oceanic and remote airspace domains but it could also increase the availability of many of the service classes in the domestic airspace as a backup to terrestrial communications systems. The main drawback of Swift Broadband is the challenge of certification of a commercial system for safety of life services.

The broad scope of the MCNA effort and limited schedule subtask in particular restricted the depth at which the Transition analysis and Interoperability issues could be addressed. The transition analysis was performed toward the end of the contract and concurrently with other SE tasks which limited the effectiveness of information flow between other MCNA subtasks. In addition, the schedule constraints limited the number of iterations of the overall MCNA system engineering effort that would increase the fidelity of the transition analysis. As a result there are many opportunities for further work in this area. These opportunities for further advancement of the MCNA transition and interoperability task are described below:

- Port the transition plan analysis from Access to a more powerful software tool for implementation of decision tool algorithms and analysis. Possibilities could include MATLAB, C++, or decision tool specific software packages.
- Increase the fidelity of characterizations of the operational scenarios and candidate links. For example, equipage costs of communication links depends on aircraft class. Also, the transition plan analysis indicated that there would be benefit from breaking some scenarios into multiple versions. For example, the coverage analysis indicated

that it is difficult to meet higher service levels of most of the communication classes in the polar airspace domain. This suggests that for operational scenarios that would provide benefit in the polar regions that new "light" versions of these scenarios should be defined. These new scenarios, with lower communication service level requirements, could provide coverage in the polar domain and still provide benefits. Lastly, the coverage and communication service capabilities/requirements will require review and refinement based on what was learned in all the MCNA subtasks.

- A more comprehensive transition analysis would include many other factors beyond those considered for the representational transition plans presented in this document. This would include contributions from a large range of external factors. Such a transition plan would incorporate inputs from all the other MCNA subtasks. This could lead to generating detailed transition plans for individual components of the MCNA. Optimally this would involve interacting with stakeholders and other organizations to establish an overall transition strategy.
- The equipage rates over time for the different airspace classes could be very useful for transition analysis. Equipage rates were considered in the definition of the TCSP section of this document, section 3, but a more rigorous analysis is needed.
- Incorporate detailed demand requirements of the individual communication services and the capacity capabilities of the candidate link architectures into the transition analysis. This was considered at a very high level in the definition of what communication service classes are supported by each candidate link. The more detailed work would necessitate communication loading analysis in the MCNA requirements area.
- Increase the scope of the transition analysis by including high risk high benefit scenarios. This would tend to push the current transition analysis beyond the 2015 timeframe toward the MCNA vision timeframe of 2025.

7 REFERENCES

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8 MICROSOFT ACCESS DATABASE

Once the data in the preceding tables stabilized, they were imported into Access. Figure 9 and Figure 10 show the forms used to input the MCNA data services and MCNA voices services respectively.

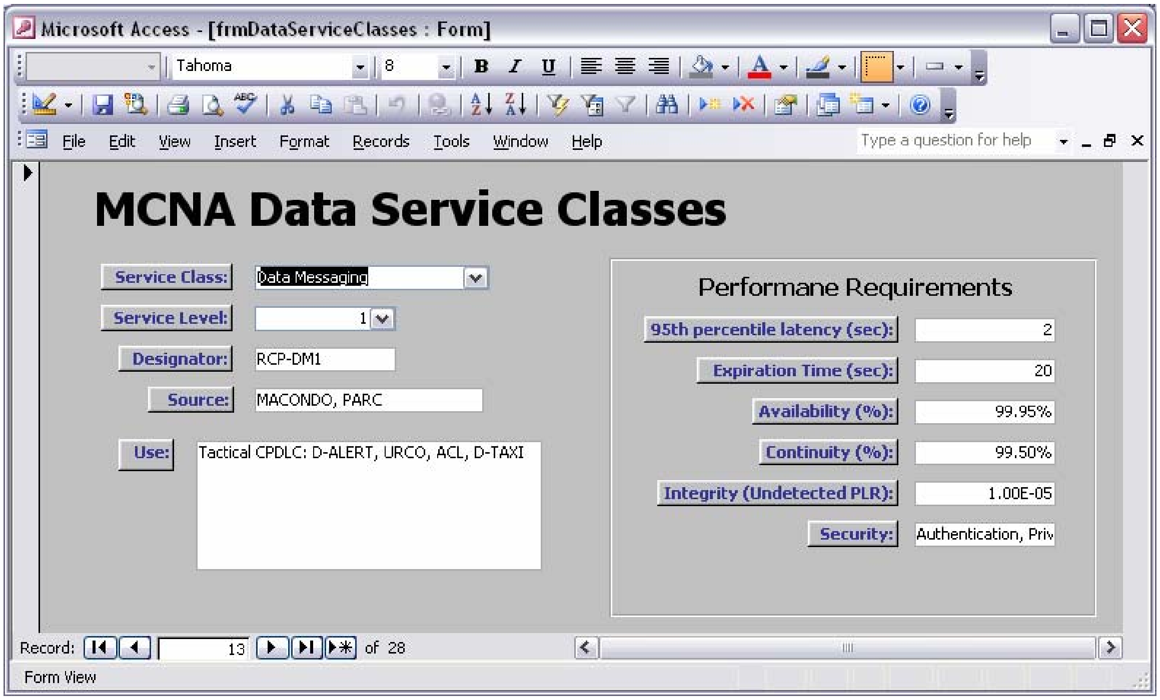

Figure 9: Data Services Access Form

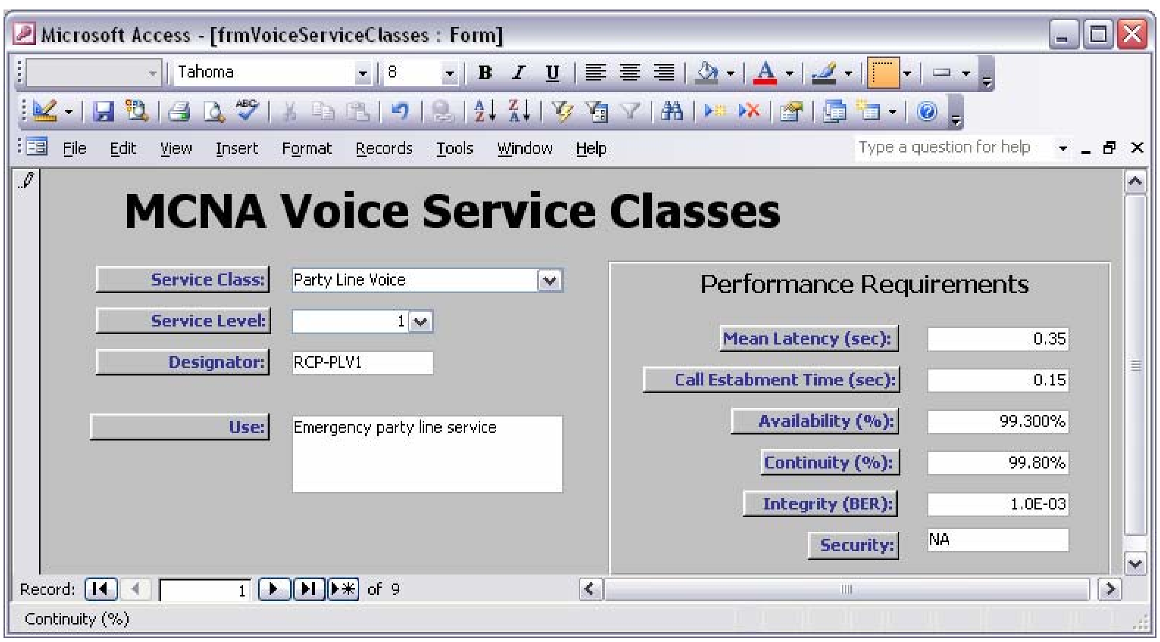

Figure 10: Voice Services Access Form.

Next the MCNA scenarios, Figure 11 and the MCNA candidate communication links, Figure 12, were entered into the access database. For each scenario and candidate link, the applicable airspace domains and aircraft classes were selected. Then, for each scenario, the required voice and data communication services were entered, highlighted in red. This information linking the scenario to the needed communication services was actually entered into what is called a subform in Access. The subform creates a table with two columns where the first specifies a scenario and the second column indicates a communication service class and service level required for that scenario. A similar subform in the candidate link form generate similar tables that stores data on what service classes and service levels can be met by each candidate link. This organization resulted in 8 tables of data described in Table 22 below.

Table 22: MCNA Transition Task Access Tables.

Table	Description
tblCommServData	Data Communication Services
tblCommServVoice	Voice Communication Services
tblCommSystems	Candidate Communication Links
tblScenarios	MCNA Scenarios
tblTraceDserSys	Data services supplied by each candidate link
tblTraceDserScen	Data services required by each scenario
tblTraceVserSys	Voice services supplied by each candidate link
tblTraceVserScen	Voice services required by each scenario

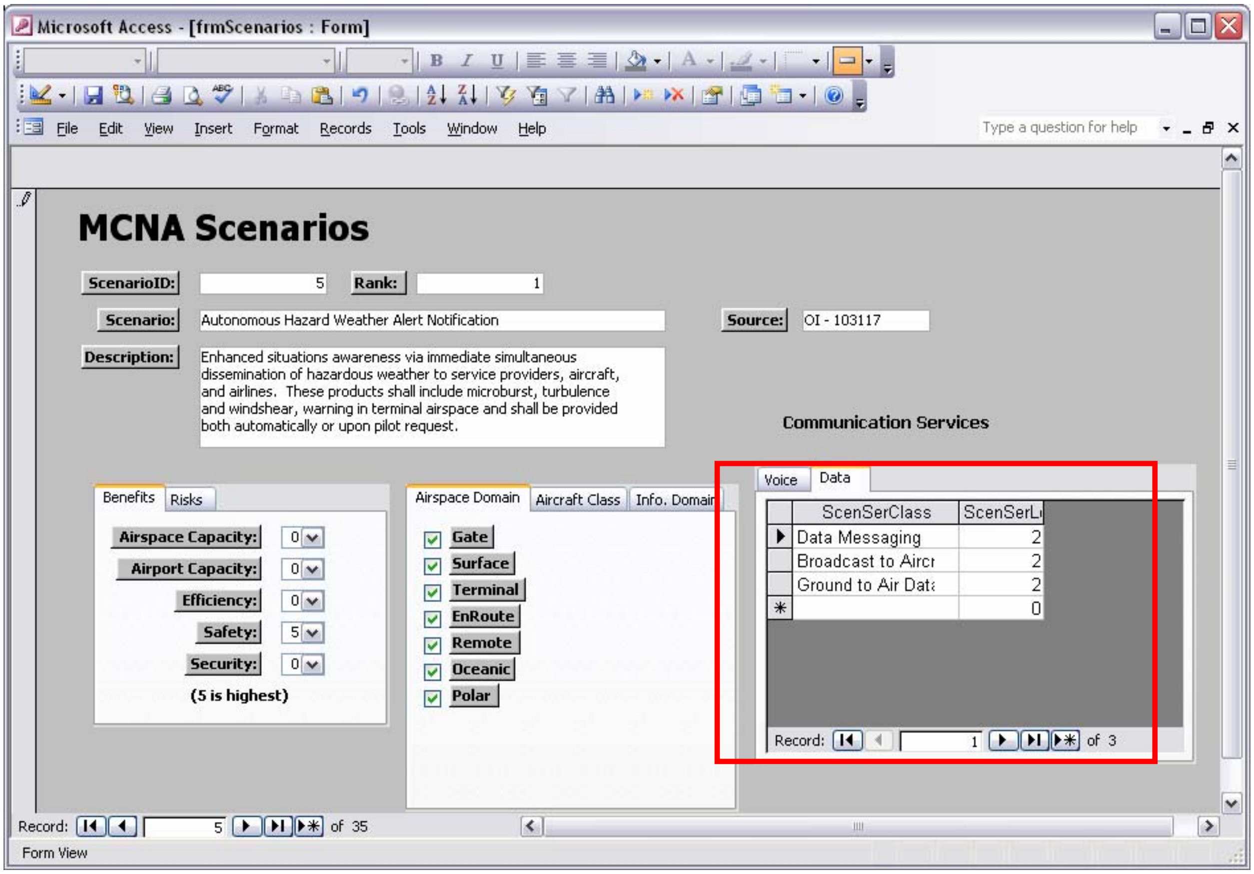

Figure 11: MCNA Scenarios Access Form.

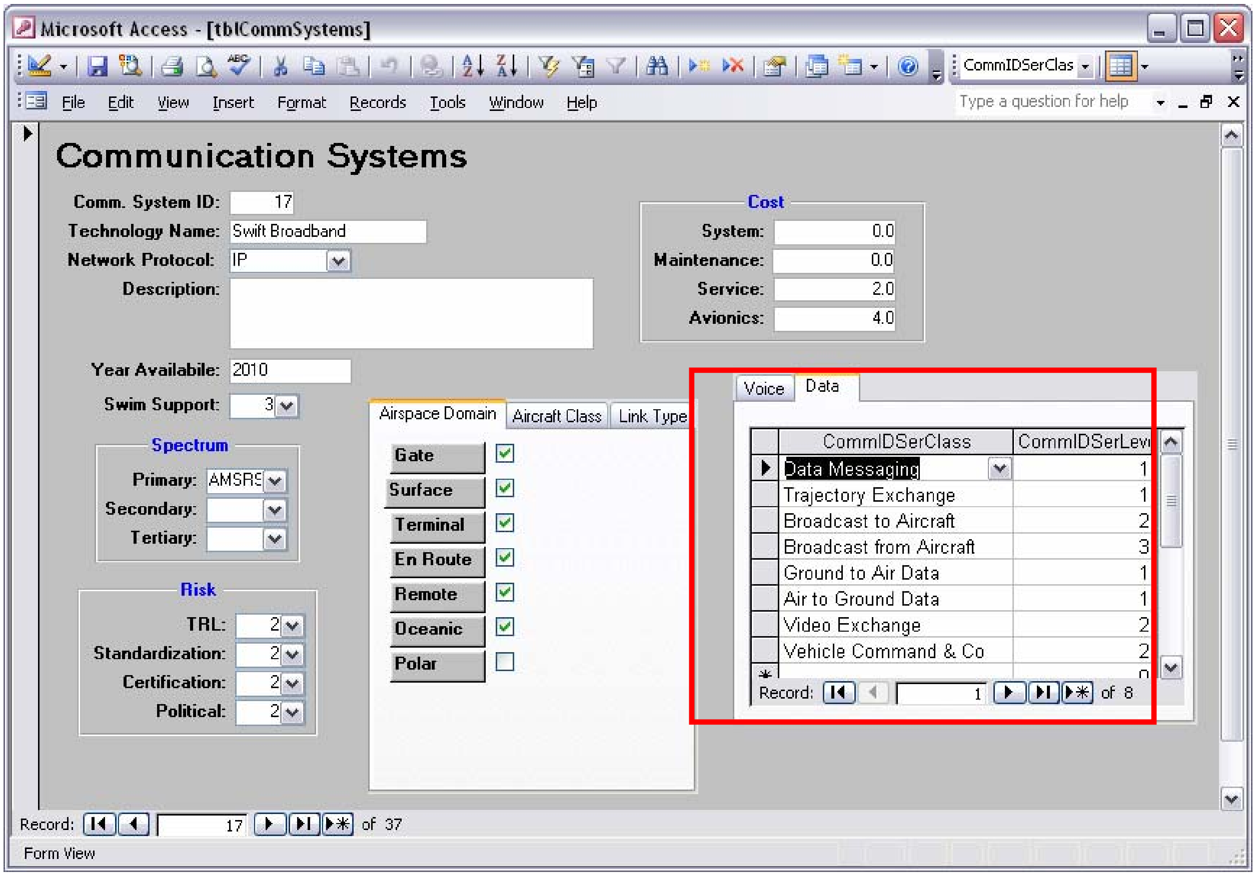

Figure 12: MCNA Communication Systems Access Form.

Once the all the data was entered into the designed data structures, the next step was to establish the appropriate relationships between attributes in these tables. Attributes in Access refers to fields in the tables of databases. For example, the data service class and level attributes in the table that contains tracks captures the needs of the scenarios, tblTraceDserScen, must be linked to the corresponding attributes in the data services table, tblCommServData. The Access representation of these relationships between tables and their attributes is shown in Figure 13. In the middle, the blue box highlights the candidate links table whose information was entered using the form shown earlier in Figure 12. The yellow box highlights the MCNA scenarios table that was entered using the form shown in Figure 11. The red highlighted tables capture the voice and data services required and supplied by the MCNA scenarios and MCNA candidate links respectively.

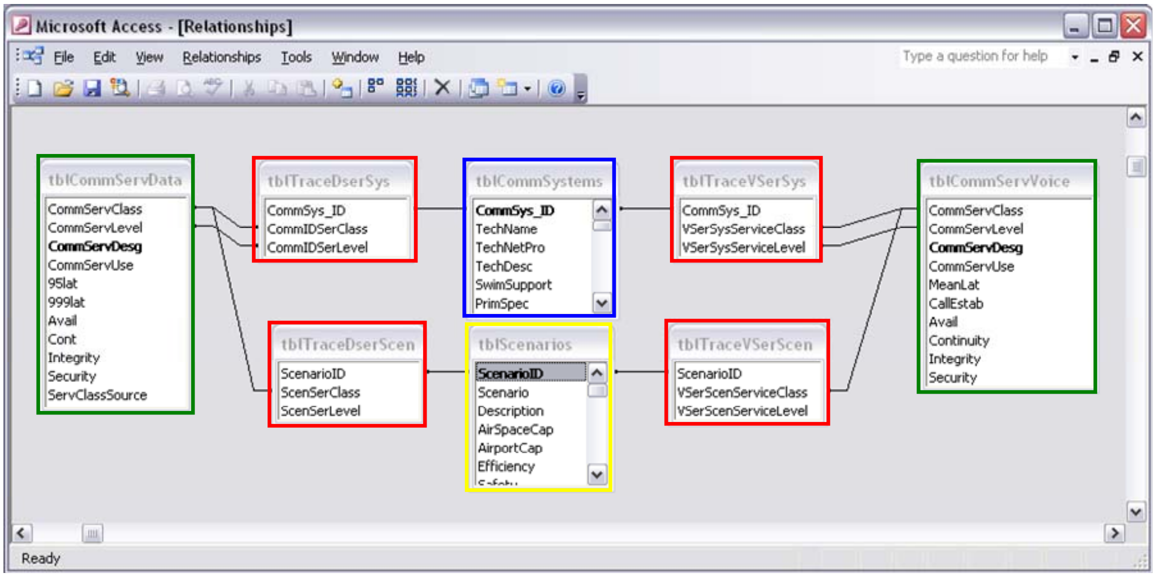

Figure 13: MCNA Access Database Table Relationships.

In the vernacular of relational databases, when a query is run with these links between the attributes in the tables the operation is called an equi-join. The results of such a query is a new table that contains the records in the tables tblScenarios and tblCommSystems and the various trace tables that have the same Communication Service Class and Service Level. Additional filters on these queries can further refine the results and provide means of determining technology gaps and candidate transition paths. Section 4 contains the results of many such queries that illustrate the relationships between the data in these tables using many different views.

Once these queries are run they can be exported into Microsoft excel for further processing and editing. Time limitations prevented the implementation of SQL programming to automate many operations which instead had to be implemented by hand. In addition while Access is useful for linking and sorting data it is not as useful in some of the more decision tool related work that became part of the transition task. This suggested a potential for further work in porting the information into another software tool (MATLAB) or programming language (C++) for additional analysis. The exact direction taken will depend on a clearer definition of how these tools would be used in follow on MCNA investigations.

9 ACRONYMS

A-A	Air to Air
A-G	Air to Ground
A/G	Aircraft Ground
AATT	Advanced Air Transportation Technologies
ACARS	Aircraft Communications Addressing and Reporting System
ACAST	Advanced CNS Architectures and System Technologies
ACD	Aircraft Control Domain
ADL	Airport Data Link
ADN	Aircraft Data Network
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance - Broadcast
AIM	Aeronautical Information Management
AISD	Airline Information Services Domain
ANCO	Advanced Network Centric Operations
AOA	ACARS Over AVLC
AOC	Airline Operations Control
AOCDL	Airline Operations Control Data Link
ARINC	Aeronautical Radio, Inc.
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
AUTOMET	Automatic Meteorological Reporting
BCA	Boeing Commercial Airplanes
BFA1	Broadcast From Aircraft level 1
BGAN	Broadband Global Area Network
BGMP	Border Gateway Multicast Protocol
CATS-I	Capability Architecture Tool Suite - Internet
CDRL	Contract Data Requirements List
CDT	Common Data Transport
CIM	Common Information Management
CLNP	Connectionless Network Protocol
CMU	Communications Management Unit
CLNP	Connectionless Network Protocol
CNS	Communications Navigation and Surveillance
CORBA	Common Object Request Broker Architecture
CPDLC	Controller Pilot Data Link Communications
DSP	Digital Signal Processing
ES	Extended Squitter
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FCAPS	Fault Configuration Accounting Performance Security
FCS	Future Communication System

FFBD	Functional Flow Block Diagram
FIS	Flight Information Service
FIS-B	Flight Information Service - Broadcast
FTI	Flight Information
GA	General Aviation
GCNSS	Global Communication Navigation and Surveillance System
GEO	Geostationary Earth Orbit
GRC	Glenn Research Center
HF	High Frequency
HFDL	High Frequency Datalink
IBM	International Business Machines
ICAO	International Civil Aviation Organization
ICOCR	Initial Communication Operating Concept and Requirements
IETF	Internet Engineering Task Force
IFR	Instrument Flight Rules
IP	Internet Protocol
ISO	International Standards Organization
J2EE	Java 2 Platform, Enterprise Edition
LRU	Line Replaceable Unit
MCNA	Mobile Communication Network Architecture
MDCRS	Meteorological Data Collection and Reporting System
NA	Not Applicable
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NCO	Network Centric Operations
NEA	Network Enabled Application
NMO	Network Management and Operations
NOCC	Network Operations and Control Center
OEM	Original Equipment Manufacturer
OSI	Open Systems Interconnection
PBR	Policy Based Routing
PC	Personal Computer
PIESD	Passenger Information and Entertainment Services Domain
PIM-SM	Protocol Independent Multicast - Sparse Mode
POA	Plain Old ACARS
PODD	Passenger Owned Devices Domain
PP	Protection Profile
QOS	Quality of Service
RCP	Radio Control Protocol
RF	Radio Frequency
ROA	Remotely Operated Aircraft
RTCA	Radio Technical Commission for Aeronautics
RTO	Research Task Order
SARPS	Standards and Recommended Practices
SDR	Software Defined Radios
SEA	SWIM Enabled Applications

SoSE	System of Systems Engineering
SOW	Statement of Work
SQL	Structured Query Language
SWIM	System Wide Information Management
T&I	Transition and Interoperability
TCAS	Traffic Alert/Collision Avoidance System
TCSP	Total Communication System Performance
TIS	Traffic Information Service
TIS-B	Traffic Information Service - Broadcast
TNAS	Transformation of the NAS
TRACON	Terminal Airspace Controlled
TRL	Technology Readiness Level
TSD	Target System Description
UAT	Universal Access Transceiver
UAV	Unmanned Aerial Vehicles
URL	Uniform Resource Locator
US	United States
VDL	VHF Data Link
VDL-B	VDL Broadcast
VDR	VHF Datalink Radio
VFR	Visual Flight Rules
VHF	Very High Frequency
WAN	Wide Area Network
XML	Extended Markup Language